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HISTORY OF SCIENCE AND TECHNOLOGY

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INTRODUCTION

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One of the perspectives that emerges from the study of the history of science and technology is the difference between science and technology. Technology's history is both longer and separate from that of science. Science is the systematic attempt to understand and explain the universe, while technology is the systematic analysis of techniques for creating and doing things. Science is devoted to the more conceptual enterprise of understanding the environment, and it relies on the comparatively sophisticated skills of literacy and numeracy.

While technology is concerned with the fabrication and use of artefacts, science is concerned with the more conceptual enterprise of understanding the environment, and it depends on the comparatively sophisticated skills of literacy and numeracy. Such skills were only accessible with the rise of the great world civilizations, so science can be said to have begun with them, around 3,000 years BCE, while technology is as old as humankind. While there were some overlaps, such as the use of mathematical principles in construction and irrigation, the roles of scientist and technologist (to use modern terminology retrospectively) remained distinct in ancient cultures. Although distinct, we will discuss their history together in this book.

This book, *History of Science and Technology*, is divided into fourteen units that follow the self-instruction mode with each unit beginning with an Introduction to the unit, followed by an outline of the Objectives. The detailed content is then presented in a simple but structured manner interspersed with Check Your Progress Questions to test the student's understanding of the topic. A Summary along with a list of Key Words and a set of Self Assessment Questions and Exercises is also provided at the end of each unit for recapitulation.

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BLOCK - I
ANCIENT AND MEDIEVAL SCIENCE AND TECHNOLOGY – A SURVEY

UNIT 1 SCIENCE AND TECHNOLOGY IN ANCIENT PERIOD

Structure

1.0 INTRODUCTION

The origin of ancient science, like the origins of any other discipline, is embedded in mystery. We should trace the source of science in the histories of human arts and institutions. If we observe the life of primitive men carefully, we would discover the presence of scientific thoughts at every stage. Science evolved through verbal interactions between human societies and later took the form of writing. Rather than looking for written sources on ancient science, we should trace the origins of ancient science in the practices of magic, religion and philosophy. The current human civilization owes a lot to ancient understanding of science. Our current mechanical techniques and social institutions carry the legacies of our ancestors to a great extent. The historians of science greatly rely upon the works of archaeologists, anthropologists and philologists to know about the scientific traditions of ancient men. They also analyse the customs and rituals of present times to understand their origin. In this unit, we will discuss the origin of science and technology in ancient period by considering Greece. It will also focus on the contribution of various thinkers to the field.

1.1 OBJECTIVES

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After going through this unit, you will be able to:

- Discuss the origin of science and technology in the ancient period
- Explain the development of science and technology in ancient Greece
- Analyse the contribution of Pythagoras, Hippocrates, Plato and Aristotle

1.2 ORIGIN OF SCIENCE AND TECHNOLOGY IN ANCIENT PERIOD

We can trace the origin of ancient science to the earliest stages of Mesopotamian culture. The famous historian of science, J. D. Bernal divided the early history of the development of human science into two stages. The first stage covers the Paleolithic or Old Stone Age, both Lower and Upper. The basic occupation of man in this stage was food-gathering and hunting. The second stage covered the Neolithic or New Stone Age. It was the period of primitive village agriculture. The first trace of urban life can be traced in this period in Mesopotamia, Egypt, India and China. The Bronze Age and the iron ages fall in this category. The civilizations of Greece and Rome emerged by the end of this period.

In each stage of human civilization, man invented new methods to make life more convenient. The techniques and ideas of primitive men were the basic features of the development of science and technology in the ancient period. In the Paleolithic Age, men learned various ways of handling and shaping materials. They first used fire which is considered as one of the greatest scientific discovery of human history. They gathered knowledge about the flora and fauna of wild nature, tamed the animals and birds, and learned to save themselves from the animal kingdom. Also in parallel, men progressed in building social relations. They invented the ideas of kinship, began to practice religious rituals, interacted with each other in specific languages, and also practiced music and painting. All these social practices of early men are closely intermingled with their inventions in science and technology.

In the Neolithic Age, village culture began. Learning agriculture was one of the biggest achievements of early humans. With the invention of agricultural practices, the social structure also began to change. The roles of males and females inside the family started evolving. Male members of the society got more and more involved in the tasks that needed physical labour. Weaving and pottery were two other ancient occupations that survived through this age and still enjoy great social significance. Pictorial symbolism and organized religion also emerged in this period. In the Bronze Age, men learnt the use of more varieties of metals and also to create new material by mixing up portions of different metals. The first signs of

architecture can be traced during this time. The wheel, another magnanimous invention, along with other mechanical devices, started to be used. The first signs of city can be found in this period.

With the emergence of the city, science and technology took a giant leap. A complex society emerged with its intellectual and economic life and new political systems. The discipline of mathematics progressed faster with the expansion of commerce and trade. The invention of numbers, especially the zero, added new fervour to scientific thoughts. Writing culture also developed fast. The usage of letters replaced the pictorial forms of writing. With this, a new class society emerged with its logic of hierarchy and division. Governments were formed and the idea of state came to the fore. With governments patronizing education and culture and rulers taking personal interests in the spread of science, the distinguished disciplines of astronomy, medicine and chemistry became popular.

The Iron Age did not mark any drastic transformation from the previous eras. The new invention of this period was glass. Moreover, the tools and machines already in use were improved and advanced. The chief contribution of the Iron Age was the introduction of iron, a cheap metal at that time that ensured human civilization spread far and wide. In parallel, the social and economic inventions of alphabet, money, politics and philosophy caused rapid development in the spread of science and technology. In this period, the great Greek civilization emerged. The ancient Greeks gathered all the scientific knowledge of the previous eras and set-up a unique economy, society, culture and government system. The rationale of Greek science is recognized even in our present societies.

While we study about the greatness of the ancient cultures, we should also keep in mind that the practice of social evils such as slavery, oppression, suppression of women—were integral parts of these societies. Constant warfare and social conflict ravaged the routine life of men. The Roman Empire made its appearance amidst many unsolved problems and unaddressed miseries. The Roman Empire had to offer very little in the field of science and technology. It contributed more to the practices of public works and law. Due to this contradictory nature, the Roman Empire gradually went into eclipse, giving way to the Asian world. India, Persia and China appeared as great spaces where the practices of science and technology made their marks. In this unit, you will discuss about the various aspects of ancient Greek science.

Check Your Progress

1. Mention the two stages of the early history of the development of human science.
2. State any two significant features of the Bronze Age.

1.3 SCIENCE AND TECHNOLOGY IN GREECE

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It is generally accepted by historians that the origin of ancient Greek science was in the cities of Asia Minor, particularly Miletus. This region of western Asia located close to the cradles of ancient civilizations facilitated exposure to science and technology. At that time in the northern parts of the Mediterranean, in Greece, Italy and Sicily, the power of the old landed aristocratic classes was challenged by a new tyrant group, who were mainly local rulers. This new class was patronized by the trading fraternity. The 6th century BC was marked by the violent expansion of the Greek colonies. Marseilles, Naples, Sicily and to the east as far as the Black Sea, came under the jurisdiction of Greek rule. The significance of early Greek civilization was that it tried to give explanation of the cosmos and the universe. The Greeks formulated a theory of human existence and left written records of their scholarship.

The early stages of Greek science were dominated by the group of thinkers who subsequently came to be known as 'philosophers'. Socrates called them the lovers of wisdom. In their own time, they were called sophists or wise men. We know very little about this group of people. Their writings are mostly available to us in the quotations of Plato and Aristotle's texts. The sophists were also exponents of religious mysteries. They founded numerous semi-monastic communities resembling schools. They were mainly patronized by the new class of tyrants who replaced the old aristocrats. For example, Pericles gave space to the philosopher Anaxagoras in his court. The philosophers were generally from affluent families and had high social status. Some of them like Protagoras accepted fees for teaching. Plato criticized him for doing so.

The city of Athens came into prominence by the end of the Persian wars in 479 BC. With the passage of time, it took a leading place in the economic and cultural worlds of the Greeks. Wealth poured into Athens as trade flourished in the adjacent regions. Circulation of money increased with the extensive use of the Laurion silver mines. A strong government was set-up by efficient rulers and a firm navy power was established to extend mastery over the sea-borne commerce. Artists, sculptors, historians and philosophers gathered in the city and prospered its intellectual life. Pericles, the great politician, befriended the philosophers like Anaxagoras and patronized the practice of science and philosophy. Greek science, by its nature, was autonomous and developed its own particular character.

The first famous Greek philosopher, whose name survives through ages, was Thales. He propounded the theory that everything was originally water in the beginning. Earth, air and all living beings were generated from liquid water. This theory had close proximity to the thoughts that appeared in the Book of Genesis, a myth about creation circulating in ancient Sumerian culture. Probably the location of Greece on the coastline of the Mediterranean and the interconnections of the

land and sea gave birth to these thoughts. Thales, however, did not recognize the existence of any creator. That is the reason as to why he is considered as a materialistic scientist deeply interested in nature. He took all natural matters as alive. He can be called a hylozoist (matter-life).

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Thales' successors kept up the tradition of the materialism and atheism evident in his thoughts. Anaximander and Anaximenes explained many other mysteries of nature basing their thoughts on the hypothesis of Thales. For them, earth, mist and fire were the basic 'elements' out of which this whole universe was created. Heraclitus modified the theory further. In his opinion, everything flows (*pantarhei*). He considered fire as the prime element. It was fire that could transform and change everything. We get his quotation, 'all things are an exchange for fire, and fire for all things, even as wares for gold, and gold for wares.' He also observed that materials often behave in opposite ways. Some things like flame, tends to move up and others like stone, fall downwards. Though the idea of gravity was unknown, but a contemporary theory of dialectical philosophy was derived from this concept. Heraclitus explained that the co-existence of opposite forces was necessary. It generated a tension like the bow and its string.

Empedocles was one of the prominent students of the materialistic philosophers. He was the first scientist to discover that air too had material substance even though it was invisible. He demonstrated it with experiments. He imagined an order in the primitive elements of nature. Earth, water, air and fire remained one above the other. He connected mental tendencies with natural ones. He thought that opposite psychological conditions like love and hate also had mechanical explanations. The elements of nature mixed up and separated in order, and that gave rise to such mental states. This tendency to connect the mental world with the physical world had its parallel in ancient China where the opposite forces were conceived as male and female, fire and water, which was commonly known as the Yin and Yang dualism.

The ancient Greek scientists explained everything as continuous mutual transformation of material elements. The later day philosophers laid more emphasis on the static nature of material elements and considered them fixed and unalterable. Here is the triumph and uniqueness of early Greek science. The problem of this scientific practice, however, was the comparative explanations of the social and the natural worlds. This did not explain either clearly. It also prevented the emergence of astronomy, medicine and chemistry in this period.

Check Your Progress

3. Name the first famous philosopher of Greece.
4. What was the contribution of Empedocles in Greek history and culture?

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1.4 PYTHAGORAS

The great mathematical tradition of Pythagoras had its origin in the Babylonian astronomy. Anaximander (611-547 BC) calculated the distance of the stars, moon and the sun. The great contribution of Pythagoras (582-500 BC) was the attribution of numbers to all aspects of Nature. He was born in Samos, an island near Miletus, and migrated to south Italy. Here he founded a school, religious and philosophic in nature. The school began a tradition of philosophical thoughts that produced great exponents like Plato. Some historians tend to think Pythagoras a mythical figure. In fact, it is not clear how much of his teachings were his original thoughts. His theorem on the right-angled triangle was well-known in Egypt. It is possible that the whole tradition of Pythagorean mathematics was borrowed from Eastern thoughts. But the school that bore his name was real enough. The school set-up connections between mathematics, science and philosophy.

Pythagoras blended two elements in his teaching, the mathematical and the mystical. He explained everything with numbers. Number was at the centre of all his thoughts. He used numbers to explain geometry on the one hand and physics on the other. He linked eternal soul to the eternal forms of numbers. For him, the whole universe was built up of pure numbers. The followers of Pythagoras invented geometrical rules by insisting that there were five regular solids in the cosmos whose sides could be drawn from triangles, squares and pentagons. They successfully drew a pentagon with the help of rulers and compass which was a mathematical triumph. Euclid’s famous discoveries were deeply embedded into Pythagorean principles.

The most well-known Pythagorean theories probably came up after the death of the great master. The followers of Pythagoras debated on the rationality of numbers and thus split into two schools. One group believed that measures were unreal; the other adopted the idea of the irrational within the concept of numbers. The Pythagoreans acknowledged the importance of circle and sphere in astronomy. They believed that the earth was a sphere and the sun and moon were planets like the earth. All the planets were moving round an invisible central fire. Heraclides (375 BC) and Aristarchus (310-230 BC) gave this theory a rational shape and ultimately it came closer to the modern thought on the solar system.

In physics too, the followers of Pythagoras applied their fetishism for numbers. There were direct connections between old popular traditions of magic and mysticism. Orphism, the ancient slave religion, had deep influence on Pythagorean philosophy. Even Hindu and Buddhist philosophies deriving from India had influenced the ancient Greek thoughts. Probably, Pythagoras did not directly borrow from Indian philosophy but the striking similarities provoke someone to think about the linkages between ancient civilizations. The Pythagoreans talked about purification through knowledge. They divided human beings into three categories: the first were those buy and sell, the second were the competitors, and

the third were the spectators. The third category only contemplated and was deemed far superior by the Pythagoreans. Thus, the idea of pure science as deep contemplation has been carried to the present time. This also has a dangerous side. It encourages in one way, the practice of knowledge without responsibility. Historian G. Thomson regards Pythagoras as the first exponent of democratic thought. He established the rationality of the merchant middle classes as against the interests of the old landed aristocracy.

The influence of Pythagoras lasted through time. Two main branches of philosophy derived from his thoughts. One was led by Parmenides and also by Plato. The former took up the abstract and logical aspects of Pythagorean mathematics while the later formed the basis of his mysticism and idealism on this thought. On the other hand, Pythagorean number theory directly influenced the atomic theory of Leucippus of Miletus (475 BC) and Democritus of Abdera (420 BC). In applied science, the theory of Pythagoras helped reducing all physical quantities to measures and numbers. In mathematics, the influence of this school helped to establish the method of proof through deductive reasoning from postulates. The geometrical theorems owe their origin to Pythagorean thought.

The philosophers who carried on the Pythagorean tradition to the future, the most prominent among them was Parmenides (470 BC) of Elea in south Italy and his pupil Zeno (450 BC). Parmenides is known as the philosopher of pure reason. He vehemently opposed the scientific practices through observations and experiments and proposed the importance of numbers as the very basis of all science. He believed in pure reason and numbers constituted the basics of it. He thought that absolute and certainty could only be accessible through numbers while all other methods of science were full of fallacies. In later days, the famous German philosophers Hegel and even Karl Marx heavily borrowed from the thoughts of Parmenides. His pupil Zeno attacked the basic principles of Pythagorean theory. He ultimately proved that time and space could neither be continuous nor discontinuous. Zeno observed some great paradoxes in nature which were extensively used by mathematicians of future generations.

Democritus, the exponent of the famous atomic theory, tried to solve many questions posed by Parmenides and his disciples. He refused to accept the vision of the universe as ideal numbers. He rather imagined a world made out of small innumerable uncuttable (a-tomos) particles, atoms moving in the void of empty space. Democritus rejected the idealism and mysticism of Pythagorean philosophy and retained its mathematical contents; especially the importance of geometry. Democritus is also celebrated as the pioneer of the idea of void in philosophy. Void, also termed as vacuum or nothingness, shocked contemporary thinkers. For most of them, the universe was full and thick with substance. In fact, many later scientific traditions, like Galileo’s dynamics, the laws of gases, the invention of the steam engine, proved the idea of vacuum as faulty. The very basis of the great debate between Hobbes and Boyle in the 17th century was the idea of vacuum in nature and in politics.

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The atomic theory was intensely political in nature since the very beginning for its evidently materialistic character. It was also considered a heresy during the Classical period though Epicurus and Lucretius applied it in their works on philosophy and ethics. The atomic theory stood against the theories of divine origins of the world. It inspired the thoughts on free will of man and many other philosophical thoughts that would get popularity in Renaissance Europe. Gassendi, the first modern atomist, directly borrowed his ideas from Democritus and Epicurus. Newton full-heartedly supported the atomic theory and wrote extensively about it. Finally, John Dalton drew from his thoughts and founded the atomic theory of chemistry. Though the advanced atomic theories of modern physics are not exactly similar to the ancient Greek ones, but it cannot be denied that the origin of atomic theories can be traced back to the Classical period.

Check Your Progress

5. Name the two major elements blended by Pythagoras in his teaching.
6. Name the two main philosophers who carried forward Pythagorean tradition.

1.5 HIPPOCRATES

Ancient Greek medicine had two approaches; one was empiric, and second philosophic. According to Greek legends, Greek doctors belonged to the clan of Asclepius, the demi-god of Medicine. The emergence and development of scientific, rational and professional medicine in classical Greece is associated with the name of Hippocrates. The Greeks responded in a variety of ways to disease. Faith in magical practices, rejection or avoidance of the diseased was common in Greek society. The great warrior Philoctetes, who was bit by a snake, was made an outcast. The spread of epidemics was often looked at as divine causation even though scientific explanation of disease was gaining popularity with the passage of time. Medicine had to compete with magical and religious approaches.

A bunch of medical texts, known as the 'Hippocratic writings', survived from the classical age. These were probably written in the mid-late 5th century BCE, a period when scientific and philosophical thoughts were on the rise. These texts were written by authors with considerable medical experience. They include specialized treatises about various kinds of diseases, about therapeutic techniques, about food, drink, and medicaments about the nature and structure of the human body, and about specific functions such as nutrition, reproduction, and sense perception. The texts were not only informative but they also served the purpose of medical teaching as well. The texts contained literary qualities and rhetorical skill. It seems that some of these texts were orally presented in front of the listening audience and patients.

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The above mentioned medical texts are generally associated with the Greek doctor Hippocrates and his school of medicine. But now, it is generally accepted that Hippocrates was one among many doctors and the spreading of the medical tradition was more than a one-man task. In fact, very little information is available about the legendary Hippocrates. He hailed from Cos. The corpus of medical treatises attributed to his name was probably written between 450 and 350 BC. Now, it is universally agreed that a single medical writer could not be the author of more than sixty works of his time. Also, a plethora of more hundred-and-seventy medical works was attributed to him in later times. All these are assembled under the *Hippocratic Corpus*. Some of the works show great intellectual affinity with each other, while some works criticize the ideas mentioned in another. The most well-known works in the bundle are *Of the Epidemics* 1 and 3, *Prognostic*, *On Airs, Waters and Places*, *On the Sacred Disease*, *On Joints*, *On Fractures*, *Ancient Medicine*, and *Nature of Man*. Works like the *Epidemics* seem to be written by more than one author. The formation of the *Hippocratic Corpus* began probably in Hellenistic Alexandria. Aristotle's school in Athens too had contributed to it.

There are some special features in the Hippocratic texts. One of the most famous quotations was when he warned the physicians not to feed patients suffering from fever: 'Life is short, and the Art long; the opportunity fleeting; experiment dangerous, and judgment difficult. Yet we must be prepared not only to do our duty ourselves, but also patients, attendants, and external circumstances must co-operate.' The author/s discussed and reflected upon each medical case separately. Often the shadows of Egyptian medical practices loomed large in the texts.

Hippocrates denounced magical, religious or divine explanation of diseases. A passage on the 'sacred' disease epilepsy suggests the following: 'It seems to me that the disease called sacred is no more divine than any other. It has a natural cause, just as other diseases have. Men think it divine because they do not understand it….. In Nature all things are alike in this, that they can all be traced to preceding causes.'

The school of Cos was equally intolerant to the application of philosophy to medicine though in later years medical practitioners heavily relied on philosophy. Even the Hippocratic writings contain such thoughts. With the growth of anatomical and physiological studies, the interconnections between mind and body began to form the central questions of medical practice. Alcmaeon, a follower of Pythagoras, learned the function of nerves by dissecting the human body and concluded that the brain and not the heart was the organ of sensation and movement. Philolaus formulated the doctrine of the three spirits or souls of man: the vegetative spirit, which he shares with all growing things, situated in the navel; the animal spirit, shared with breasts only, which gives sensation and movement, in the heart; and the rational spirit, possessed only by man and located in the brain.

The doctrine of the four humours propounded by Empedocles seriously challenged the medical practices of classical Greece. Empedocles blended his

cosmological ideas with his medical theories. He thought that the four fundamental elements that he called the 'root of things', were present in the human body and in all animate beings. According to this theory, man was a microcosm, a small world modelling in himself the great world, the macrocosm. The four elements of the world – fire, air, water and earth – were matched by the four humours of the body – blood, bile, phlegm and black bile. Also, they were considered as the four sacred colours of alchemy – red, yellow, white and black. Thus, Empedocles explained man as sanguine, choleric, phlegmatic or melancholic. This novel explanation of human body and spirit superseded the Hippocratic school of medicine for the next centuries. Thus, the 'Hippocratic' and 'non-Hippocratic' writings both equally contributed to the medical practices of classical Greece.

Check Your Progress

7. What is known as the 'Hippocratic Corpus'?
8. What was the doctrine of the three spirits or souls of man formulated by Philolaus?

1.6 PLATO AND ARISTOTLE

Plato (428-348 BC), an Athenian from an aristocratic background, was a pupil of Socrates, the great orator. Plato took the path of idealism in philosophy and is considered as one of the greatest exponents of this concept. Plato's ideas were written in a dialogical form, a new genre introduced to philosophical writings. Plato authored two famous treatises, *Republic* and *Laws*, in which he argued for a governmental system in which the old privileges of the aristocratic classes would be preserved, but at the same time this system would provide spaces for the lower orders. Plato categorized the citizens in his *Republic* into four groups: the guardians; the philosophers, who ruled; the soldiers, who defended; and the people who did all the work. This class division was to be made permanent. Plato suggested that a 'noble lie' was to be circulated about God creating men of four kinds: gold, silver, brass and iron. In Plato's imagination: 'if the rulers find a child of their own whose metal is alloyed with iron or brass, they must, without the least pity, assign him the station proper to his nature, and thrust him out among the craftsmen and farmers. If, on the contrary, these classes produce a child with gold or silver in his composition, they will promote him, according to his value, to be a Guardian.'

Plato hoped that this rigid class system would serve as the very basis of a stable government. The guardians would have responsibility only of the state. They would devote all their energy to the service of the government. They would receive thorough education in philosophy, mathematics and music. Plato tried to apply his method on the philosopher-princes of contemporary Greece. He trained Dionysius the younger, tyrant of Syracuse, in philosophy and mathematics, though the prince failed to meet Plato's expectations. Plato's *Republic* had a diverse reception in

the subsequent eras. In the Middle Ages, when various parts of Europe were ruled by illiterate despots, the ideas proposed in the *Republic* seemed highly progressive. Since the 19th century, however, the part on class division began to face vehement criticism from all quarters of thinkers and Plato was even categorized with the systems of Capitalism and Fascism.

Plato explained human soul in his beautiful prose. He drew his ideas from many contemporary Greek philosophers and added his own valuable thoughts to it. For him, certain abstract conceptions were absolute and eternal, independent of sense impressions and to be grasped only by the eyes of the soul. He meant the triad of absolute values: truth, goodness, and beauty. He borrowed the first idea from Parmenides, the second from Socrates, while the third was his own contribution. Plato enriched the contemporary traditions of Greek sciences through his insightful vision. He coined the new word astrology that meant reasoning (*logos*), to replace the old word astronomy that was merely ordering of the stars (*nomos*). It emerged as the study of the stars. Plato did not contribute any unique thought to the field of mathematics but enriched the Pythagorean tradition by adding his own thoughts to the science of numbers and geometrical diagrams.

Plato preached his thoughts at Athens in the groves of the hero Academus to a very select number of pupils. On the gate of the Academy it was written: 'Let No One Ignorant of Mathematics Enter Here.' The Academy continued to spread Plato's ideas for nearly one thousand years until Justinian closed it in AD 525. The influence of Plato, however, far exceeded the borders of the Academy. Christianity adopted many of his thoughts. After the closing of the Academy, his original works were forgotten. The Arabs discovered some of his works and translated them. Renaissance Europe of sixteenth and seventeenth centuries critically read Plato's works and produced commentaries on them. The scientists of the Renaissance, Kepler, Galileo and Newton were directly influenced by Plato's thoughts.

Aristotle, the most famous disciple of Plato, dissociated himself from the Academy after Plato's death. He founded a rival school of philosophy, the Lyceum. Aristotle was born in Stagira in the year 384 BC. His father Nicomachus was a physician at the court of Macedonia. At the age of seventeen, Aristotle moved to Athens and joined Plato's Academy. In 335 BC, the city of Athens was *de facto* under Macedonian rule. Under Macedonian protection, he taught in his own school Lyceum until the unexpected death of Alexander the Great in 323 BC. As the news of the death reached Athens, Aristotle had to leave the city. He retreated to Chalcis, where he died in the year 322.

Aristotle occupies a central space in the history of science, politics and poetics. He was a logician and a scientist rather than a moral philosopher. Though he was a direct student of Plato, he found Plato's ideas out of date. Aristotle contributed to the fields of logic, physics, biology and the humanities. He was the founder of all these subjects and introduced a new subject Metaphysics for the ideas that could not be included in the former four. The basis of his logic was the

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idea of classification. Aristotle was a great encyclopedist too. He tried to make sense of Nature, the flora and fauna around him and left accounts of them. His great contribution to the field of natural science was that he added fifth element *ether* to the four fundamental elements of nature, fire, air, water and earth. Aristotle had his own ideas about the origin of the universe. Later, his thoughts were adopted by the Catholic Church as the basis of Christian faith of origin.

Aristotle considered physics as the key to understand the world. By 'physics' he meant the nature of everything. This included questions like: why stones fall and also questions like why men become slaves. Aristotle imagined the physical world and the social world as each other's images. In the natural world, all elements had their places. Commotion happened only when there was a disorder. Aristotle propounded the theories of motion and vacuum. For him, natural motion was final while all other motion required a mover. He thought there could not be any vacuum in nature. Aristotle's physics had many fallacies which he compensated through his biological writings. He explained that all the elements of nature crave to gain perfection. And that is the secret of natural order. Aristotle drew up a scale of Nature at the bottom of which were the minerals, over those vegetables, then more and more perfect animals, with man at the top. This was in no sense a predecessor of Darwin's theory of evolution. Aristotle imagined nature's elements as static and unchanging.

He thought man was the most perfect social animal. Beyond man there was only God. Man contained in himself three souls of spirits: the vegetable soul, the animal soul and the rational soul or *nous*. The last belonged to man alone. All the souls attained perfection gradually. Aristotle's Lyceum worked more as a research institute than a university. It was probably subsidized by Alexander the Great. The students here collected information about everything around them, from animals, plants, natural beings, to the social and natural forms of literature and constitution of cities. Aristotle's thoughts were extensively adopted by the Arabs and were greatly appreciated in Renaissance Europe.

Check Your Progress

9. Name two famous works authored by Plato.
10. Name the new subject founded by Aristotle.

1.7 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The early history of the development of human science has been divided into two stages. The first stage covers the Paleolithic or Old Stone Age, both Lower and Upper. The second stage covered the Neolithic or New Stone Age.

2. Two significant features of the Bronze Age are as follows:
   i. In the Bronze Age, men learnt the use of more varieties of metals and also to create new material by mixing up portions of different metals.
   ii. The wheel, another magnanimous invention, along with other mechanical devices, started to be used.
3. The first famous Greek philosopher, whose name survives through ages, was Thales. He propounded the theory that everything was originally water in the beginning.
4. Empedocles was one of the prominent students of the materialistic philosophers. He was the first scientist to discover that air too had material substance even though it was invisible. He demonstrated it with experiments. He imagined an order in the primitive elements of nature. Earth, water, air and fire remained one above the other. He connected mental tendencies with natural ones. He thought that opposite psychological conditions like love and hate also had mechanical explanations.
5. Pythagoras blended two elements in his teaching, the mathematical and the mystical.
6. The philosophers who carried on the Pythagorean tradition to the future, the most prominent among them was Parmenides (470 BC) of Elea in south Italy and his pupil Zeno (450 BC).
7. A plethora of more hundred-and-seventy medical works was attributed to Hippocrates in later times. All these are assembled under the *Hippocratic Corpus*. Some of the works show great intellectual affinity with each other, while some works criticize the ideas mentioned in another. The most well-known works in the bundle are *Of the Epidemics* 1 and 3, *Prognostic*, *On Airs, Waters and Places*, *On the Sacred Disease*, *On Joints*, *On Fractures*, *Ancient Medicine*, and *Nature of Man*. Works like the *Epidemics* seem to be written by more than one author.
8. Philolaus formulated the doctrine of the three spirits or souls of man: the vegetative spirit, which he shares with all growing things, situated in the navel; the animal spirit, shared with breasts only, which gives sensation and movement, in the heart; and the rational spirit, possessed only by man and located in the brain.
9. Plato authored two famous treatises, *Republic* and *Laws*, in which he argued for a governmental system in which the old privileges of the aristocratic classes would be preserved, but at the same time this system would provide spaces for the lower orders.
10. Metaphysics was the new subject founded by Aristotle.

1.8 SUMMARY

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- We can trace the origin of ancient science to the earliest stages of Mesopotamian culture.
- In each stage of human civilization, man invented new methods to make life more convenient. The techniques and ideas of primitive men were the basic features of the development of science and technology in the ancient period.
- In the Neolithic Age, village culture began. Learning agriculture was one of the biggest achievements of early humans.
- The Iron Age did not mark any drastic transformation from the previous eras. The new invention of this period was glass. Moreover, the tools and machines already in use were improved and advanced.
- It is generally accepted by historians that the origin of ancient Greek science was in the cities of Asia Minor, particularly Miletus. This region of western Asia located close to the cradles of ancient civilizations facilitated exposure to science and technology.
- The city of Athens came into prominence by the end of the Persian wars in 479 BC. With the passage of time, it took a leading place in the economic and cultural worlds of the Greeks.
- The first famous Greek philosopher, whose name survives through ages, was Thales. He propounded the theory that everything was originally water in the beginning. Earth, air and all living beings were generated from liquid water.
- Empedocles was one of the prominent students of the materialistic philosophers. He was the first scientist to discover that air too had material substance even though it was invisible. He demonstrated it with experiments.
- The great mathematical tradition of Pythagoras had its origin in the Babylonian astronomy. Anaximander (611-547 BC) calculated the distance of the stars, moon and the sun. The great contribution of Pythagoras (582-500 BC) was the attribution of numbers to all aspects of Nature.
- Pythagoras blended two elements in his teaching, the mathematical and the mystical. He explained everything with numbers. Number was at the centre of all his thoughts. He used numbers to explain geometry on the one hand and physics on the other.
- The most well-known Pythagorean theories probably came up after the death of the great master, Pythagoras. The followers of Pythagoras debated on the rationality of numbers and thus split into two schools. One group believed that measures were unreal; the other adopted the idea of the irrational within the concept of numbers.

- The philosophers who carried on the Pythagorean tradition to the future, the most prominent among them was Parmenides (470 BC) of Elea in south Italy and his pupil Zeno (450 BC).
- Ancient Greek medicine had two approaches; one was empiric, and second philosophic. According to Greek legends, Greek doctors belonged to the clan of Asclepius, the demi-god of Medicine.
- A bunch of medical texts, known as the 'Hippocratic writings', survived from the classical age. These were probably written in the mid-late 5th century BCE, a period when scientific and philosophical thoughts were on the rise.
- The doctrine of the four humours propounded by Empedocles seriously challenged the medical practices of classical Greece.
- Plato (428-348 BC), an Athenian from an aristocratic background, was a pupil of Socrates, the great orator. Plato took the path of idealism in philosophy and is considered as one of the greatest exponents of this concept.
- Plato hoped that this rigid class system would serve as the very basis of a stable government. The guardians would have responsibility only of the state. They would devote all their energy to the service of the government.
- Plato preached his thoughts at Athens in the groves of the hero Academus to a very select number of pupils.
- Aristotle occupies a central space in the history of science, politics and poetics. He was a logician and a scientist rather than a moral philosopher. Though he was a direct student of Plato, he found Plato's ideas out of date.
- Aristotle considered physics as the key to understand the world. By 'physics' he meant the nature of everything.

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1.9 KEY WORDS

- **Sophists:** This term was used for wise men who existed in Ancient Greece. They held specialization in more than one subject and subsequently came to be known as philosophers.
- **Hylozoist:** This term is used for a believer in hylozoism. This concept refers to one who holds that matter, and every particle of it, has a species of life or animation.
- **Orphism:** It is a name given to the religious beliefs and practices which emerged in Ancient Greece.
- **Dialogical:** It refers to the use of conversation or shared dialogue to explore the meaning of something.

1.10 SELF ASSESSMENT QUESTIONS AND EXERCISES

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Short-Answer Questions

1. Write a short note on the development of science and technology in Greece.
2. Briefly mention the significant influence of Pythagoras theories on the development of science and technology.
3. What were the significant features of the Hippocratic texts?

Long-Answer Questions

1. Discuss the origin of science and technology in the Ancient Period.
2. 'The emergence and development of scientific, rational and professional medicine in classical Greece is associated with the name of Hippocrates.' Elucidate the statement.
3. Critically examine the influence of Plato in the fields of science and religion.
4. 'Aristotle occupies a central space in the history of science, politics and poetics.' Discuss.

1.11 FURTHER READINGS

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UNIT 2 SCIENCE AND TECHNOLOGY IN ROME AND ISLAMIC CIVILIZATION

Structure

2.0 INTRODUCTION

The Roman Empire was one of antiquity's most technologically advanced cultures, with some of the more advanced concepts and innovations being lost during the tumultuous Late Antiquity and early Middle Ages periods. During the Middle Ages and the beginning of the Modern Era, some of the Romans' technical feats were gradually rediscovered and/or improved upon, with some, such as civil engineering, building materials, transportation technology, and certain innovations like the mechanical reaper, not being improved upon until the 19th century. Roman engineers supplied the ancient world with technology that was ahead of its time, from building hundreds of miles of roads to maintaining a water source that could support millions of people. Similarly, the Islamic civilization made a significant contribution to the field of science. In this unit, we will discuss the science and technology in Rome with contribution of thinkers like Galen and Ptolemy. We will also focus on contribution of Arab civilization to the fields of science and technology.

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2.1 OBJECTIVES

After going through this unit, you will be able to:

- Describe the significant developments in the field of science and technology in Rome
- Discuss the major contribution of Galen and Ptolemy
- Elaborate on the Arab science by focusing on contribution of Avicenna

2.2 ROMAN SCIENCE AND TECHNOLOGY: GALEN AND PTOLEMY

The people of the Roman civilization had several remarkable scientific and technological achievements that they had done using technical know-how lost in the Middle Ages and revived in the 19th and 20th centuries. For instance, they used insulated glazing, which was not revived until the 1930s. Their innovations were also inspired by Greek designs. However, Roman artisans guarded their technologies as trade secrets.

Although the Romans were well-known for their architectural designs, categorized as 'classical architecture' akin to Greek architectural designs, they were inspired by the Greeks in terms of designs and proportions of the building structures. However, apart from the composite and Tuscan orders of columns and the design of the dome, inspired by the Etruscan arch, the contribution of the Roman civilization was relatively less until the end of the republic.

The Romans started to use cement and concrete in almost all their constructions starting from the 1st century BC. This construction material soon replaced marble as the main building material used by the Romans and let them experiment with many radical architectural designs, such as domes, barrel vaults and cross vaults. These vaults were used to build aqueducts that carried fresh water into towns.

The Romans used their knowledge of engineering-related concepts to build sewage systems that kept the town clean and healthy. In the same century, Vitruvius wrote *De architectura*, considered to be the first treatise on ancient architecture. Romans also started to do glassblowing soon after it was invented in Syria about 50 BC. Most of the scientific achievements of the Roman civilization were in the realms of engineering and medicine. They devised ways to mine silver, gold and lead and developed water mills to grind grain. They used their vaults.

Romans and sailing

The naval forces of ancient Rome played an important role in the conquest of the Mediterranean basin. However, they never got their place of pride in the annals of Roman history because the Romans were essentially land based and depended on

the Greeks and Egyptians to build and operate their ships. Also, they did not possess any autonomy possessed by modern-day fleets and ships.

The Romans ventured into sailing and ship building only after the First Punic War in 264 BC. This was also the time when they waged a war against the Carthaginians, who were descended from the Phoenicians and were excellent sailors, developed a naval force and tried their hand at ship building. Soon after, in 100 BC, Rome conquered Phoenicia, and there was no looking back for the ship-building industry for the Romans. This was the phase when the Roman navy underwent rapid and massive expansion and played a vital role in establishing the dominance of the civilization in the Mediterranean region. In the 1st century BC, the Roman navy played an important role in the war against pirates and in the civil wars that ushered the defeat of the Republic.

By the time Phoenicia was conquered by Rome and its control over the Mediterranean region established, the need for a naval fleet had diminished. Only some patrol boats were needed to control piracy and monitor merchant ships. Mostly, the crews of these ships were Phoenicians, Greeks or Egyptians who came from sailing cultures. In the Late Empire, the Roman emperors needed all the tax money for foot soldiers, so they pretty much stopped supporting the navy.

Even though the Roman navy did not gain much prominence, under their control the Mediterranean Sea saw a lot of movement of trade ships. The ship-building industry also witnessed tremendous improvement during this time. The development of triangular sails, which replaced the earlier square sails and first appeared around 50 BC, was the most important improvement.

Engineering and construction

The Romans brought a number of innovations in the construction of roads, aqueducts and bridges. The architecture of the Etruscan civilization had a great influence on Roman architecture.

The Romans used to make cements with the help of pozzolanic ash or pozzolana. The material added to cement to make concrete was generally made from pumice. This is similar to modern Portland cement concrete. Around 20 BC, a Roman architect named Vitruvius introduced a low-water-content technique to mix concrete.

Some historians also believe that the Romans began using a lot of concrete in their building in AD 60, i.e., during the reign of Emperor Nero. They covered concrete with the help of bricks for aesthetic purposes.

When the Romans realized that insulated glazing help in keeping buildings warm, they started using this technique in the construction of public baths. Some of the historians believe that the Romans used cranes for construction work.

Roads

The Romans constructed roads mainly for their military. The length of their road network was 85,000 kilometres. Their government maintained a number of way stations along the roads. These way stations provided the facility of refreshment to the military.

The Romans also maintained a separate system for changing stations so that private and official couriers could change stations easily. This system helped in fast dispatch as a dispatch could cover 800 kilometres in 24 hours with the help of horse relays.

For the construction of roads, they used to dig a pit. This pit was filled with sand, gravel and rocks. After this, a layer of concrete was used to cover the filling. Then, the road was cemented with polygonal rock slabs.

Roman roads were considered the most advanced roads constructed until the early 19th century. These roads were resistant to floods as well as many other environmental hazards. They were used for over 1000 years even after the fall of the Roman Empire.

Sewage

In the beginning, the Romans did not have a proper sewage treatment system. People used to often fall ill or die due to contaminated water. Later, they built aqueducts which carried fresh water and also constructed public latrines. The Romans built sewage pipes which used to carry sewage from the street and throw it in rivers. This shows that they were either not aware of any method of sewage treatment to kill germs or they did not understand its importance.

Aqueducts

An aqueduct is a navigable channel which was constructed to supply water. The Romans constructed a number of aqueducts. Eleven aqueducts, made of limestone, used to supply over 1 million cubic metres of water each day to the city of Rome.

The mountain springs were the source of water supply. From mountain springs, the water used to go to the aqueduct. Then, it was collected in tanks and supplied to people through pipes. The amount of water inside the aqueducts depended on gravity. Thus, these aqueducts could transport a large amount of water.

In places, when water had to cross an area that was sunk below, the Romans used inverted U-shaped pipes to force water up. Modern-day humans have not been able to match the technological standard and fine tolerance of Roman aqueducts till date.

Bridges

Roman bridges were made of stone. These were structured in the form of arches and were really large and strong. The Pons Aemilius Bridge, later named Ponte Rotto, was built in 142 BC. It is the oldest Roman stone bridge in Rome.

Trajan's bridge built by Apollodorus of Damascus was the biggest Roman Bridge. Nobody could build such a long bridge for over a millennium after its construction. Most of the bridges made by the Romans were 60 feet above water bodies.

Roman Military Technology

The Roman military had personal equipment, armaments as well as deadly siege engines such as ballistas, scorpions and onagers. The siege engines used by the Romans were unique but they were perhaps the first people to put ballistas on carts for better mobility. They had heavy and elaborate armour such as *cataphracts* and chainmail armour. These armours were popular as these were inexpensive, easy to produce as well as maintain and could fit anyone.

Soon they also made an armour, called *loricasegmentata*, that was lighter and covered the complete chest area. It was made of segmented plates and could protect all the vital areas of the body. The plate bands used in this armour were costly and were difficult to produce and repair. The Roman military used all kinds of armours as per their convenience and preference.

Numerals

The Romans used Roman numerals as well as Greek numerals. They did not show any consistency in the use of numerals. Sometimes, they used Roman numerals and at other times, they used the Greek numerals. However, people could understand what the other one meant perhaps because everyone was aware of both number systems.

2.2.1 Ptolemy

Ptolemy, the Greek mathematician, astronomer and poet, was born in Egypt when it was under the control of the Romans. Thus, he can be called a Roman citizen. But, he is generally assumed to be of Greek descent because he descended from a Greek family, studied in a Greek school in Alexandria and wrote in the Greek language. He is considered to be the greatest scholar of his time, who wrote extensively on cosmological topics, including conjunctions, eclipses, occult and transits. His biggest contribution is the *Almagest*, a treatise comprising thirteen books that gives a detailed presentation of the mathematical theory of the motions of the Sun, Moon and the planets. However, his theories were superseded by Copernicus who presented his heliocentric theory in 1543.

Ptolemy also made maps, in which he followed Eratosthenes in regard to the latitudes and longitudes. However, his maps were more accurate than those of Eratosthenes'. In the maps made by Ptolemy, the outlines of the Mediterranean and Atlantic coasts, up to as far north as the Baltic and Scandinavia, were mostly accurate. He also got the outlines of West Asia, the Arabian Peninsula and the Persian Gulf mostly correct.

What Ptolemy got wrong was his theory that the Earth was at the centre of the universe and the sun, stars and the moon revolved around it. In this, he derived his inspiration from Aristarchus, and instead of verifying his theory, he developed explanations in support of planetary motion around the Earth. According to his theory of retrograde motion, if the planets revolve around the Earth, some of them may shift direction and go backwards for a while. In support of this, he developed complicated mathematical formulae to predict when the planet would go into retrograde motion.

2.2.2 Galen

Aelius Galenus (AD 129-216), often Anglicized as Galen, was a physician, surgeon and philosopher in the Roman Empire. Considered to be one of the most accomplished of all medical researchers of antiquity, Galen influenced the development of various scientific disciplines, including anatomy, physiology, pathology, pharmacology,and neurology, as well as philosophy and logic.

The Romans began learning about medicine from the Greeks. In fact, most of the Roman doctors came from Greece. Galen was one of the most popular Roman doctors who wrote a medical book as well. The shortened version of his book was used by Europeans for more than thousand years.

Galen believed in the theory of four humours and blood-letting. According to the theory of four humours, an excess or deficiency of any of the four bodily fluids, namely black bile, yellow bile, phlegm and blood, influenced people's personality and health. Similarly, blood-letting is the withdrawal of little quantities of blood from a patient to cure or prevent a disease.

He also made a number of observations about the insides of human bodies. He made these observations after looking at swordsmen and wounded soldiers. He was aware of a few functions of nerves, heart and brain of human body. However, he did not make any advances in treating people and continued using blood-letting as a method of treatment.

Galen's principal interest was in human anatomy, but Roman law had prohibited the dissection of human cadavers since 150 BC. Due to this restriction, Galen performed anatomical dissections on living (vivisection) and dead animals, mostly focusing on primates. This work was useful because Galen believed that the anatomical structures of these animals closely mirrored those of humans. Galen clarified the anatomy of the trachea and was the first to demonstrate that the larynx generates the voice. In one experiment, Galen used bellows to inflate the lungs of a dead animal. Galen's work on the anatomy remained largely unsurpassed and unchallenged until the 16th century in Europe. In the middle of the 16th century, the anatomist Andreas Vesalius challenged the anatomical knowledge of Galen by conducting dissections on human cadavers. These investigations allowed Vesalius to refute aspects of Galen's anatomy.

Check Your Progress

1. What kind of construction material was used by Romans since the 1st century BC?
2. Name the oldest stone bridge built in Rome.

2.3 ARAB SCIENCE AND TECHNOLOGY

A thousand years ago, the Islamic world was abuzz with ideas spanning science, culture and economics. Baghdad — virtually unrecognizable from the city it has become today — was at its beating heart, home to 'the House of Wisdom,' where scholars translated classical foreign texts into Arabic, and were said to have built the greatest collection of knowledge in the world. Algebra, astronomy, medicine, and chemistry all flourished in an era sometimes romanticized in the West as a 'golden age.'

In the medieval Islamic world, science was also known as Islamic science or Arabic science. It was developed and practised during the Islamic Golden Age (c. 750 CE – c.1258 CE). During this period, scientific knowledge in Indian, Iranian, Syriac and particularly Greek language was translated into Arabic. During the Middle Ages, these translations became important sources for significant scientific developments by scientists from the Islamic civilization.

Within the Islamic civilization, scientists were of different ethnicities. A major section was Persian, followed by Arabs, Moors, Syrians, Somalis and Egyptians. They were also from different religious backgrounds, with most of them being Muslims, Christians, Jews and also non-religious people.

2.3.1 Avicenna (Ibn Sina)

Ibn Sina, often known in the West as Avicenna, was a Persian polymath who is regarded as one of the most significant physicians, astronomers, thinkers and writers of the Islamic Golden Age, and the father of early modern medicine. His famous works are *The Book of Healing*, a philosophical and scientific encyclopaedia, and *The Canon of Medicine*, a medical encyclopaedia which became a standard medical text at many medieval universities and remained in use as late as 1650. Besides philosophy and medicine, Avicenna's corpus included writings on astronomy, alchemy, geography and geology, psychology, Islamic theology, logic, mathematics, physics and works of poetry.

Avicenna belonging to the 10th and 11th centuries has an important place in the history of medicine in Iran and the world. Furthermore, the modern medicine is laid upon the infrastructure of his medicine. Research on history of medicine has concluded that from 11th to 17th centuries, the scientific and educational activities

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of medicine in the world were moving on the pivot of Avicenna medicine or under its intensive influence.

Avicenna's scientific fame and influence was not only spread in Iran and the Islamic world, but also extended to the whole world. He is still known as a universal scientist in particular in medicine in the views of the researchers and historians of the science history. The Avicenna's medicine-which became the representative of Islamic medicine- is mainly manifested in his important and famous work *al-Canon* fi *al Tibb* (The Canon on Medicine).

Despite the fact that the medicine of Avicenna and in general the Islamic medicine was based on Hippocrates and Galenus, but according to the views of the researchers of history of medicine, Avicenna could over-ride both in theoretical medicine and practical medicine from his predecessors and his book of *Canon* could overshadow all previous scientific works.

In the heritage of Islamic medicine, the names of tens of outstanding physicians and hundreds of medical works are shining, but the name of Avicenna and his book of *Canon* in the Islamic east and the Christian west enjoys a specific position. Since the age of Avicenna up to the present, more than 200 commentaries, annotations, abridgements and translations in different languages of his book of *Canon* have been made. These statistics are unprecedented as compared to the works of other Islamic physicians.

2.3.2 Islamic Civilization

The term 'Islam' refers to the Islamic religion and the Islamic civilization which developed around the religion. Islamic civilization comprises of several cultures and faiths, even though, the proportion of Muslims among its population has increased significantly over time.

Islamic Prophet Muhammad (c. 26 April 570 – 8 June 632) was the founder of the religion of Islam. After his death, Islam expanded continuously under the leadership of Muslim rulers, who were known as Caliphs. During this time, struggle for leadership of the growing religious community started and continues even today. The early periods of Islamic history after the death of Prophet Muhammad are known as the Umayyad Caliphate. The Abbasid Caliphate was the third of the Islamic caliphates and it was the ruled by the Abbasid dynasty of caliphs.

During the Umayyad Caliphate, the Islamic empire started to strengthen its territorial gains. The Arabs became the ruling class and made Arabic the language of administration.

Islamic thought and civilization

The Islamic history, known as High Caliphate, was significantly developed between the phase of the Umayyad Caliphate and the early phase of Abbasid Caliphate. This period ranges between the years 692 and 945, and it came to an end when local Muslim rulers in Baghdad—the traditional seat of power—marginalized the

caliphate. From 945 to 1238 when Baghdad was destroyed by the Mongols, the caliph continued to be a figurehead with power being increasingly transferred to local Amirs.

Steady and secure political structures were established and trade prospered during the High Caliphate. The Chinese were experiencing modernization in commerce, and the trade routes between China and Islamic territory expanded both overland and along the coastal routes. Even though Islamic civilization mainly focused on agriculture, commerce started playing a vital role as the caliphate secured peace within the empire. Before the Arab conquests, wars and cultural divisions had separated people. This gradually paved way to a new civilization which incorporated different ethnic and religious backgrounds. Arabic language was used in this new Islamic civilization as transmitters of culture, and it significantly became the language of commerce and government.

Eventually, the significant religious and cultural works of the Islamic civilization were translated into Arabic. As the population started understanding Arabic gradually, they began to recognize Islam as their religion. The rich cultural heritages of this civilization mainly comprised of strong Hellenic, Indic, Syrian and Persian influences. Besides, the intellectual traditions of the Greek were also extensively recognized, translated and studied. This process allowed the Islamic population to gain access to all the significant works of all the cultures of the empire. This further enabled the formation of a new common civilization, based on the religion of Islam. As a result, a new era of high culture and innovation developed, where these different influences were well recognized and given their respective places in social consciousness.

Sphere of Islamic thought and culture in the High Caliphate

The religious scholars of Islam comprised of both men and women, and were collectively known as the *ulama*. These scholars were very influential in the Islamic society, particularly in the fields of Sharia law, speculative thought and theology. Their statements were recognized as the external practice of Islam, including prayer and the details of the Islamic ways of life. They also had a strong hold over the government and the laws of commerce. Although they were not rulers, they were recognized as keepers and upholders of the rule of law.

On the other hand, among the religious, there were successors of the more compelling expressions of Christianity and Buddhism, in the Sufi orders. These Muslims approached their religion in a more informal and varied manner. Islam also expressed itself in other, more cryptic forms that was believed to have significantly affected the public discourse during times of social instability.

The lives of the professional, the courtly and genteel classes were infused with polite, worldly culture, generally known as *adab* in Islamic tradition. These classes, which comprised Muslims and non-Muslims, particularly those of more refined taste, widely appreciated art, literature, poetry, music and even some aspects

of religion. Various new trends and topics were discussed at the Baghdad courts, which flourished widely across the lands of Islam and were quickly adopted by the Islamic civilization.

Besides these traditions, an important science was *falsafa* (Greek philosophy), which included the sciences and the philosophy of the ancients. Before the advent of Islam, *falsafa* was widely recognized across Mesopotamia and Iran. Although these 'sciences' were opposite to the teachings of Islam and the ways of the *adab* in several ways, they held a high esteem in the society. However, these outlooks and practices were endured by the *ulamas* with reservation. Besides, some *faylasufs* earned a good living through the practices of astrology and medicine.

2.3.3 Islamic Scientific Achievements

The roots of Islamic science were mainly based on Indian, Iranian and Greek knowledge. The extent of Islamic scientific achievements includes a wide range of subjects, some of which are discussed below.

1. Mathematics

In medieval Islam, mathematics was often known as Islamic mathematics or Arabic mathematics. This subject includes the body of mathematics, which was developed and preserved under the Islamic civilization between c. 622 and 1600. Islamic science and mathematics thrived under the Islamic caliphate. It was recognized well across the Middle East, expanded from the Iberian Peninsula in the west to the Indus in the east, and further moved on to the Almoravid Dynasty and Mali Empire in the south.

Islamic mathematicians had a strong influence on the scientific developments in Europe. These developments were further improved by their own discoveries and innovations, which they had learnt from Greeks, the Babylonians, the Syrians, the Indians, etc.

Some of the important contributions of the Islamic mathematicians are discussed as follows:

(a) **Algebra:** Algebra was the most important contribution of the Islamic mathematicians. They merged both Indian and Babylonian mathematical concepts along with the Greek geometry to develop algebra.

(b) **Irrational numbers:** Irrational numbers were invented by the Greeks. However, they were not very satisfied with their discovery and were only able to draw a distinction between magnitude and number. The Greeks believed that magnitudes changed constantly and could be used for units such as line segments, whereas numbers were discrete. According to the Greeks, irrationals could only be handled geometrically, and therefore, Greek mathematics was primarily geometrical. The distinction between magnitude and number was slowly removed by Islamic mathematicians, including AbûKâmilShujâ

ibn Aslam (an Egyptian Muslim mathematician during the Islamic Golden Age). They made irrational quantities to appear as coefficients in equations and to be solutions of algebraic equations. Although they freely worked with irrationals as objects, they did not closely examine the nature of the irrational numbers.

(c) **Induction:** Inherent traces of mathematical induction can be traced back to c. 300 BC when Greek mathematician, Euclid, proved that the number of primes is infinite. French mathematician, physicist, inventor, writer and Catholic philosopher, Blaise Pascal, gave the first specific formulation of the principle of induction in his *Traité du triangle arithmétique* (Treatise on the Arithmetical Triangle), which was published in 1654. Before this, Islamic mathematician, Al-Karaji, introduced the implicit proof by induction for arithmetic sequences. This was further continued by Muslim mathematician, astronomer and physician of Jewish descent, Ibn al-Samaw'al, who used it for special cases of the binomial theorem and properties of Pascal's triangle.

2. Astronomy

During the Islamic Golden Age, several significant astronomical developments were made, which were known as Islamic astronomy or Arabic astronomy. These developments and innovations, which were mostly written in Arabic, were significantly found in the Middle East, Central Asia, Al-Andalus (as Islamic Spain was earlier called) and North Africa, and later extended to the Far East and India.

Like other Islamic sciences, Islamic astronomy was also an assimilation of foreign concepts and learning. These were merged with Islamic characteristics to create Islamic astronomical science. Some of the significant foreign sources included Greek, Sassanid and Indian works in particular, which were translated into Arabic and were further modified. Later, Islamic astronomy had a significant influence on Indian, Byzantine and European, as well as Chinese and Malian astronomy.

Arabic names are still used for several important stars in the galaxy, including Aldebaran and Altair, and for astronomical terms, such as, almucantar, alhidade and azimuth. Today, there is still a large corpus of literature from Islamic astronomy, which comprises around 10,000 manuscripts. These manuscripts are scattered throughout the world, and several of them have not yet been read or recorded.

According to Associate Professor of Arabic and Islamic Studies at Georgetown University (Washington), Ahmad Dallal, the pre-Islamic Arabs depended completely on empirical observations as opposed to the Greeks, Indians and Babylonians, who had developed elaborate systems of mathematical astronomical study. These observations were based on the rising and setting of particular stars. This area of astronomical study was known as *anwa*, which continued to be expanded after Islamization by the Arabs. During this period, mathematical methods were added by Islamic astronomers to their empirical observations.

Professor David King states that the rise of Islam propagated the religious responsibility to determine the *qibla* and prayer times. This further stimulated more progress in astronomy for several centuries. English engineer and historian of science and technology, Donald Routledge Hill, classified Islamic astronomy into the four following three distinct time periods in its history:

(i) 700-825: Several Persian and Indian texts were translated into Arabic during this period. *Zîj al-Sindhind*, written by Al-Khwarizmi (c. 780-850) in 830, was the most distinguished of the texts. The text was translated by Muhammad ibn Ibrahim al-Fazariand Yaqub ibn Tariq in 777, after an Indian astronomer visited the court of caliph, Al-Mansur, in 770. Another notable text translated was the *Zij al-Shah*, a collection of astronomical tables compiled in Persia over two centuries. Some important sections of texts during this period shows that Arabs implemented the sine function—which they inherited from India—in place of the chords of arc used in Greek trigonometry.

(ii) 825-1025: Vigorous investigation was carried out during this period. In this period, the superiority of the Ptolemaic system of astronomy was acknowledged and important contributions were made to it. Abbasid caliph, Al-Mam'un, strongly supported astronomical research activities, which were mainly carried out in Baghdad and Damascus. The caliphs not only extended financial support to these activities but also regarded the works in high esteem.

Al-Khwarizmi's *Zîj al-Sindhind* was the first major Muslim work of astronomy, which includes tables for the movements of the sun, the moon and the five planets that were known at the time. The work also introduced the Ptolemaic concepts into Islamic science and marked a defining moment in Islamic astronomy. Until this time, Muslim astronomers had implemented an important method of research to the field of astronomy, translating works of others and learning knowledge, which had already been discovered. Al-Khwarizmi's works introduced the beginning of non-traditional methods of study and calculations.

Another notable work, *Kitab fi Jawani* (meaning 'A compendium of the science of stars'), was written by Persian astronomer, Al-Farghani, in 850. The book mainly summarized Ptolemaic cosmography. It also rectified Ptolemy on the basis of the discoveries of earlier Arab astronomers. In his book, Al-Farghani gave revised values for the obliquity of the ecliptic, the precessional movement of the apogees of the sun and the moon, and the circumference of the earth. The book was widely recognized by the Muslim world and was also translated into Latin.

(iii) 1025-1450: During this period, a unique Islamic system of astronomy prospered. The era started with the questioning of the Muslim

astronomers about the framework of the Ptolemaic system of astronomy. However, these criticisms remained within the geocentric framework and followed the astronomical concept of Ptolemy. According to a historian, these works were described as 'a reformist project intended to consolidate Ptolemaic astronomy by bringing it into line with its own principles'.

Another important work during the period 1025 and 1028 was *Al-Shuku ala Batlamyus* (meaning 'Doubts on Ptolemy'), written by Ibn al-Haytham, a prominent scientist and polymath from the Golden Age. He criticized elements of the Ptolemaic models while upholding the physical reality of the geocentric model. This work posed challenges which were taken up by several astronomers. Another notable work, *Tarik al-Aflak,* was published by Persian physician, Abu Ubayd al-Juzjani, in 1070. In his work, he discussed the supposed 'equant' problem of the Ptolemaic model, and also proposed a solution for the problem. In Al-Andalus, the anonymous Andalusian work, *al-Istidrak ala Batlamyus* ('Recapitulation regarding Ptolemy'), included a list of objections to the Ptolemaic astronomy.

Other important Muslim astronomers of the period included the following:

- Mu'ayyad al-Din al-'Urdi (c. 1266)
- Nasir al-Din al-Tusi (c. 1201–74)
- Qutb al-Din al Shirazi (c. 1311)
- Sadr al-Sharia al-Bukhari (c. 1347)
- Ibn al-Shatir (c. 1375)
- Ali al-Qushji (c. 1474)

3. Observatories and instruments during Islamic civilization

According to historical reports, the first systematic observations in Islam seem to have taken place under the patronage of Al-Mam'un. During this period, in several private observatories from Damascus to Baghdad, meridian degrees were measured, solar parameters were set-up, and detailed observations of the sun, moon and planets were carried out.

Under the encouragement of the Buwayhid dynasty, extensive works in astronomy was majorly undertaken during the tenth century. Some of these works include the construction of large scale instruments with which observations were made in the year 950. During this period, Adud al-Dawla, the emir of the Buwayhid dynasty in Iran, patronized the great astronomer, Abd Al-Rahman Al Sufi, who systematically revised Ptolemy's catalogue of stars. A similar observatory was established in Baghdad by Sharaf al-Daula, the Buyidamir of Kerman and Fars (983-988/9) and Iraq (987-988/9).

The first large observatory was constructed, probably in Isfahan, by Malik Shah I, the Seljuq Sultan. In Isfahan, Persian polymath, Omar Khayyám, along with many other collaborators, established a zij and formulated the Persian Solar

Calendar, also known as the jalali calendar. A modern version of this calendar is still used officially in Iran.

However, another important observatory was constructed by the Mongol ruler, Hulegu Khan, during the 13th century. Here, the technical construction at Maragha was supervised by Nasir al-Din al-Tusi, a Persian polymath and prolific writer. The facility had resting quarters for Hulagu Khan, and also a library and a mosque. Moreover, significant astronomers of the period gathered here to discuss their findings and research activities. Their collaboration brought about significant modifications to the Ptolemaic system over a period of fifty years.

Another large observatory was constructed in Samarkand in 1420 by Timurid ruler, Ulugh Beg, who was also an astronomer and mathematician. The remains of this observatory were excavated in 1908 by Russian teams. Finally, a large observatory was established in Istanbul in 1577 by Taqi al-Din Muhammad ibn Ma'ruf, an Ottoman Turkish and Muslim polymath. The observatory was on the same scale as those in Maragha and Samarkand. However, the observatory did not survive long as it was destroyed in 1580.

Instruments

There are two major sources that provide us with information regarding the devices used by Muslim astronomers. These sources are the following:

i. Devices that can be found with private collectors and at museums
ii. Treatises and manuscripts from the Middle Ages that have successfully been preserved

Muslims have immensely contributed to improving the implements and devices that were in use before their advent. Some of these improvements were in the form of addition of new details and introduction of new scales of measurement. They have also abundantly contributed to instrumentation in the field of astronomy.

(i) Celestial globes and armillary spheres

There was extensive use of celestial globes to solve problems of celestial astronomy. At present, there are 126 such instruments all over the world. Out of these, the oldest instrument belongs to the 11th century. These instruments can be used to calculate the altitude of the sun, or the right ascension and declination of stars. The input used for the calculation comprises details concerning location of the observer on the meridian ring of the globe.

An armillary sphere could be used for the same purpose. There are no remains of early Islamic armillary spheres. However, a number of treatises on 'the instrument with the rings' had been authored. One of the instruments of Islamic development that has survived till date is the spherical astrolabe. Nevertheless, there is only one complete instrument of this kind, belonging to the 14th century, which still exists.

(ii) Astrolabes

A large number of Islamic countries manufactured brass astrolabes. These instruments were primarily used to know the correct direction of (*Qibla*) Kaaba from any place on the Earth. The first known sample dates to the year 315 (which corresponds to 927-8, according to the Islamic calendar). In the book, *Golden Age of Persia*, Richard Nelson Frye states that Fazari was the first man who created the astrolabe. Although the Greeks had already invented astrolabes for knowing the location of stars, their version was very primitive and had ample scope for improvement. Fazari made significant changes resulting in a more sophisticated astrolabe. The Arabs then endeavoured to perfect it, at the time of the Abbasid Dynasty. Then it became useful for marking the beginning of Ramadan, the hours of prayers, in addition to plot the direction of Mecca.

There were instruments that were created to know the time the sun rose and the time it set. Al-Zarqali was an astronomer from Andalusia who made one such instrument. His instrument was not the same as others that were constructed by his predecessors. It was independent of the latitude of the observer and was useful at any location. This instrument was referred to as the Saphea in the European countries.

(iii) Sundials

A large number of significant advancements were ushered by Muslims in conceptualization and construction of sundials. These were also inherited by the Greeks. Al-Khwarizmi, a Persian mathematician, astronomer and geographer, and a scholar in the House of Wisdom in Baghdad, is famous for the tables created by him for these instruments. These tables shortened the time that was required for making specific calculations, by a great deal.

There was frequent use of sundials on top of mosques for determining the times of prayers. A landmark of the 14th century was the use of a time-keeping device at the Umayyad Mosque in Damascus. This was a creation of Ibn al-Shatir, a Muslim astronomer, mathematician, engineer and inventor of Arab origin. He served as a *muwaqqit* (religious timekeeper) at the mosque. This time-keeping device was built by him and it was a combination of a universal sundial and a magnetic compass.

(iv) Quadrants

Muslims invented many forms of quadrants. A few of these quadrants were the sine quadrant used in calculations related to astronomy and a variety of horary quadrants, used for determining time (especially prayer timings). This was done by observing the position of the sun or stars. Baghdad was very famous for the development of quadrants during the 9th century.

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(v) Equatorium

Al-Andalus is famous for the invention of the equatorium. The first recognized equatorium was probably made around 1015. The positions of the moon, the sun and planets can be determined with the help of this mechanical device. It requires no calculations or geometric models to locate a celestial body's mean and anomalistic position.

4. Islamic medicine

Historically, in the discipline of medicine, the terms Islamic medicine, Arabic medicine or Arabian medicine are used for medicines that were made during the Golden Age of Islam. Texts related to these medicines are in Arabic, the *lingua franca* of Islamic civilization. Islamic medicine spread throughout the world through interactions between Arab traditions and foreign countries. Ancient Islamic texts have been translated and used as bases for formulation of other medicines. These traditions have travelled across the globe to different nations.

Arabic medical literature has been translated in Latin, which significantly influenced the advancement of medicine in the high Middle Age and early Renaissance. Similarly, Arabic texts also translated the medical works of other cultures.

Early Muslims and those at the time of Umayyad period (AD 661-750), even contemporary Muslims, strongly believe that God has the power to cure every ailment. During the 9th century, several experiments and analyses were carried out for developing and utilizing a system of medicine based on scientific knowledge. More emphasis was laid upon the importance of health to society. Ancient Muslim physicians worked hard to find ways and enhanced sources of treatment for the human body. Medieval Islam has produced some of the greatest medical intellectuals that history has ever come across. They developed hospitals, expanded the practice of surgery, and included women in the study and practice of medicine.

Two of the most prominent Muslim medical intellectuals and physicians were Al-Razi and Ibn Sina. Particularly Ibn Sina (under his Latinized name Avicenna) demonstrated exclusive influence on the physicians of later medieval Europe. All over the medieval Islamic world, natural philosophy was the collective term given to medicine. This also had traces of the tenets of the Hippocratic Corpus and the ideas of Aristotle and Galen. The Hippocratic Corpus was a compilation of treatises related to medicine that was credited to the famous Greek physicist, Hippocrates of Cos (although this composition comprised knowledge and teachings of different authors). The medieval Islamic medical texts were similar to the Corpus in some treatises.

Encyclopaedias

Persian scientist Ali ibn SahlRabban al-Tabari's *Firdous al-Hikmah* (*Paradise of Wisdom*) wrote the first encyclopaedia of medicine in Arabic. This encyclopaedia

had seven sections. Al-Tabari, a pioneer in the field of child development, laid emphasis on strong bonds between psychology and medicine. He also stressed on the significance of psychotherapy and counselling in therapeutically treating patients. In his encyclopaedia, he described the impact of the theories of Sushruta and Chanakya on medicine, which also included psychotherapy.

Muhammad ibn ZakarîyaRâzi (Rhazes), a scientist from Persia (now Iran) had written the *Comprehensive Book of Medicine* in the 9th century. The *Large Comprehensive* was another book written by him, which had a very high demand. This book had all his compositions, which included records of clinical cases as experienced by him. Extremely useful records of treatments related to various diseases have been discussed by him in this book. Al-Razi was the first physician of medieval Islam who treated medicine comprehensively and in an encyclopaedic form. Rhazes deserves to be remembered as the first person to describe small-pox and measles most accurately.

2.3.4 Medieval Islamic Science

One of the major merits of the Islamic Golden Age was its contribution to the field of medicine. From physiology to human anatomy, from surgery to drugs, treatment and other branches of medicine, several major innovations were made during the Islamic Golden Age. The subsequent paragraphs elaborate upon the various fields such as anatomy, surgery and so on.

1. Human anatomy and physiology

Understanding the human body was one of the greatest endowments of medieval Islam. A significant advancement in the knowledge of human anatomy was made by Ibn al-Nafis, a 13th century Syrian physician. He discovered how blood flowed from the right ventricle to the left ventricle of the heart. Before Nafis' analysis of the same, people relied on the conclusions drawn by Greek physicians about the movement of blood within the human body. Nafis proved Roman physician, Galen's analysis that blood reached the left ventricle through invisible passages present in the septum. According to the former, the ventricular septum was impenetrable and it was very much devoid of invisible passages. Nafis concluded that the lungs were instrumental in carrying the blood in the right ventricle of the heart to the left. This discovery was one of the first descriptions of pulmonary circulation.

The ancient Greeks for long were under the impression that some kind of a visual spirit was emitted from the eyes that allowed an object to be perceived. However, in the 11th century, Iraqi scientist, Ibn al-Haytham, came up with an entirely new approach towards human vision. Haytham propounded that the eye was an optical instrument. From various scientific investigations, he developed his theory of image formation. This he explained through the refraction of light rays passing through two mediums carrying different densities.

2. Drugs

The domain of medicinal drugs also witnessed major contribution during the Islamic Golden Age. Physicians of this era emphasized the use of natural substances and plants for treatment. They very often used natural substances as a source of medicinal drugs such as *Papaver somniferum Linnaeus*, poppy seeds, and *Cannabis sativa Linnaeus* and hemp. However, pre-Islamic Arabia was not aware of poppy seeds or hemp until these were introduced in the 9th century AD by Persian, Greek and Indian medical literature. The Arabs considered Pedanius Dioscorides to be the greatest botanist of antiquity and followed some of his recommendations, such as hemp seeds to 'quench geniture' and its juice to cure earaches. Since AD 800, the use of poppy seeds was limited to the therapeutic realm. Use of poppy seeds was advocated to relieve pain attacks of gallbladder stones, headache, indigestion as well as pleurisy. The use of poppy seeds was also advocated to induce sleep. However, despite such advocacies, Persian physicist, Ali al-Tabari, demonstrated that the extract of opium from poppy seeds was fatal as they were poisonous.

As medical practice proliferated, hospitals came into existence, which in turn expanded the medical practice to what is currently known as surgery. Though the physicians of the Islamic Golden Age knew about the various surgical procedures from existing texts, translation from pre-Islamic medical texts was a significant step that helped in expanding the practice of surgery. Different types of operations were performed in the area of ophthalmology. Despite earlier records providing favourable outcomes of certain operations, surgery was less practiced owing to its low rate of success.

3. Medical techniques

Physicians of the early Islamic period implemented certain techniques as therapies to treat patients. The two major techniques commonly used by them to treat a wide variety of illnesses were blood-letting and cauterization. The process of surgical removal of blood was termed as blood-letting, a process used to cure a patient of bad 'tumours', which was considered detrimental to one's health. Cauterization, on the other hand, was the method which involved burning the skin or flesh of a wound, performed in order to stop bleeding and prevent infection. In order to carry out the procedure, the physicians used a heated metal rod to burn the wounded area. This would cause the blood to clot and eventually heal the wound.

4. Treatment

Patients suffering from eye complications, such as trachoma and cataracts, often resorted to surgery. Vascularization of the tissue, which invaded the cornea of the eye, was thought to be the cause of trachoma by many Islamic physicians. Trachoma was surgically rectified, which is today known as peritomy. Physicians carried out

this procedure by using an instrument to keep the eye open during the surgery. They also used a number of small hooks for lifting and a very thin scalpel for excision. A similar technique was implemented while treating the problem of trachoma. Termed as pterygium, the procedure was used to remove the triangular-shaped part of the bulbar conjunctiva onto the cornea. The growth was lifted with the help of small hooks and then a lancet was used to cut the same. However, both these surgeries were painful for the patient as well as difficult for the physician to perform.

During the Islamic medieval age, it was believed that the presence of an opaque fluid between the lens and the pupil caused cataract. Physicians of medieval Islam knew the method of treating cataract, termed as couching, through earlier medical publications. A lancet was used to make a small incision into the sclera, and then a probe was inserted and used to depress the lens, pushing it into one side of the eye. After the completion of this procedure, the eye was washed with salt water. Cotton wool soaked with rose oil and egg white was used to bandage the operated eye. The patients were instructed to lie on their backs for sometime following the surgery.

5. Anaesthesia and antisepsis

Medieval Islamic society attempted at curing patients through the process of anaesthesia and antisepsis. Before these procedures were developed, surgery was limited to fractures, dislocations, traumatic injuries resulting in amputation, and urinary disorders and so on. They invented a procedure, in which the wounded area was often cleaned with 'wine, wined mixed with oil of roses, oil of roses alone, salt water, or vinegar water'. These carried antiseptic properties. Various herbs and resins including frankincense, myrrh, cassia and members of the laurel family were also used to prevent infections.

Opium extracted from poppy seeds were known for its pain-killing purposes; physicians often made use of the same in order to treat patients. Other drugs such as henbane, hemlock, soporific black nightshade and lettuce seeds were also used by them to treat pain. Some of these drugs, especially opium, were known to cause drowsiness, and some modern scholars have argued that these drugs were used to cause a person to lose consciousness before an operation, as a modern day anaesthetic would.

Hospitals

A number of hospitals, known as *bimaristan* in Arabic, were built during the early Islamic era. *Bimaristan* in Arabic means the 'house of sick'. The idea that the hospital is a place for the sick people was an idea derived from the early caliphs. *Bimaristan* existed as early as Prophet Muhammed. The first Muslim hospital service was held in the courtyard of Prophet's mosque in the city of Medinah.

The first *bimaristan* was built in AD 707 by Ummayad caliph, Al-Walid ibn Abd al-Malik, in Damascus. The *bimaristan* had a well-equipped dispensary

and a host of qualified physicians who were paid monthly salary. The *bimaristan* treated the blind, the disabled and people suffering from leprosy. The first true Islamic hospital was built during the reign of Caliph, Harun al- Rashid.

Physics, alchemy and chemistry in medieval Islamic civilization

The Islamic world in the Golden Age was much engrossed in the study of physics. However, the Islamic world was introduced to the world of science and mathematics only through the works of Western philosophers and scholars such as Aristotle, Archimedes, Galen, Euclid and others. The works left behind a huge impact on the Muslim scholars and these works were translated into Arabic. Islamic scholarship had inherited Aristotelian physics from the Greeks, and they developed it further during the Islamic Golden Age, placing emphasis on observation and a priori reasoning, formulating crude forms of the scientific method. Various fields of study in physics included optics and magnetism, mechanics, kinematics as well as astronomy.

Scholars of the medieval Islamic world were engaged in the study of alchemy and the study of practical chemistry. The word alchemy is believed to have been derived from the Arabic word *kimia*, which in turn was derived from the Egyptian word *kemi*, meaning black. After the fall of the Western Roman Empire, the Arab world became the boiling pot of alchemical development.

Cosmology and ophthalmology in medieval Islamic civilization

Cosmology in Islamic society is mainly derived from various sources including the Quran, Hadith, Sunnah, and current Islamic as well as other pre-Islamic sources. There is a mention of seven heavens in the Quran as well as a vast universe sustained by Allah. From the 7th till 15th centuries, cosmology was extensively studied by the Islamic world.

One of the major branches of medieval Islamic medicine was ophthalmology. The oculist or *kahhal* was an honoured member of the medical profession during the Abbasid period and occupied an important position in royal households. Medieval Islamic physicians are considered to be the founders of ophthalmology, which was seen as an independent discipline in its own right. Muslim physicians are credited for coining medical terms such as ‘retina’ and ‘cataract’. They are credited for inventions such as the injection syringe, which was used in the extraction of cataract. They even described conditions such as pannus, glaucoma, phlyctenulae and others.

Cataract extraction

Extracting cataract was a major landmark in the history of ophthalmology. A seminal text in this area was the *Choice of Eye Diseases* written by the Iraqi surgeon, Ammar bin Ali Al Mawsili. He attempted the earliest extraction of cataracts through the process of suction. He invented a hollow metallic syringe needle, which he

used to successfully extract cataracts through suction. In his medical treatise, he explains how he discovered the technique of cataract extraction. In his words:

> 'Then I constructed the hollow needle, but I did not operate with it on anybody at all, before I came to Tiberias. There came a man for an operation who told me: Do as you like with me, only I cannot lie on my back. Then I operated on him with the hollow needle and extracted the cataract; and he saw immediately and did not need to lie, but slept as he liked. Only I bandaged his eye for seven days. With this needle nobody preceded me. I have done many operations with it in Egypt.'

Check Your Progress

3. Mention the significant works of Ibn Sina, better known as Avicenna.
4. Who is the founder of the religion of Islam?
5. Name two of the most prominent Muslim medical intellectuals and physicians.
6. Name the branch of medicine which witnessed development during the Islamic civilization.
7. What were the common techniques used to treat illnesses during the Islamic medieval period?

2.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The Romans started to use cement and concrete in almost all their constructions starting from the 1st century BC. This construction material soon replaced marble as the main building material used by the Romans and let them experiment with many radical architectural designs, such as domes, barrel vaults and cross vaults.
2. The Pons Aemilius Bridge, later named Ponte Rotto, was built in 142 BC. It is the oldest stone bridge built in Rome.
3. Ibn Sina, often known in the West as Avicenna has several works to his credit. His famous works are *The Book of Healing*, a philosophical and scientific encyclopaedia, and *The Canon of Medicine*, a medical encyclopaedia which became a standard medical text at many medieval universities and remained in use as late as 1650.
4. Islamic Prophet Muhammad (c. 26 April 570 – 8 June 632) was the founder of the religion of Islam.
5. Two of the most prominent Muslim medical intellectuals and physicians were Al-Razi and Ibn Sina.

6. One of the major branches of medieval Islamic medicine was ophthalmology.
7. The two major techniques commonly used by them to treat a wide variety of illnesses were blood-letting and cauterization.

NOTES

2.5 SUMMARY

- The people of the Roman civilization had several remarkable scientific and technological achievements that they had done using technical know-how lost in the Middle Ages and revived in the 19th and 20th centuries.
- The Romans used their knowledge of engineering-related concepts to build sewage systems that kept the town clean and healthy. In the same century, Vitruvius wrote *De architectura*, considered to be the first treatise on ancient architecture.
- Ptolemy, the Greek mathematician, astronomer and poet, was born in Egypt when it was under the control of the Romans. Thus, he can be called a Roman citizen.
- The naval forces of ancient Rome played an important role in the conquest of the Mediterranean basin.
- Even though the Roman navy did not gain much prominence, under their control the Mediterranean Sea saw a lot of movement of trade ships. The ship-building industry also witnessed tremendous improvement during this time.
- The Romans brought a number of innovations in the construction of roads, aqueducts and bridges. The architecture of the Etruscan civilization had a great influence on Roman architecture.
- The Romans constructed roads mainly for their military. The length of their road network was 85,000 kilometres. Their government maintained a number of way stations along the roads.
- An aqueduct is a navigable channel which was constructed to supply water. The Romans constructed a number of aqueducts. Eleven aqueducts, made of limestone, used to supply over 1 million cubic metres of water each day to the city of Rome.
- Aelius Galenus (AD 129-216), often Anglicized as Galen, was a physician, surgeon and philosopher in the Roman Empire.
- The Romans used Roman numerals as well as Greek numerals. They did not show any consistency in the use of numerals.
- Within the Islamic civilization, scientists were of different ethnicities. A major section was Persian, followed by Arabs, Moors, Syrians, Somalis and Egyptians. They were also from different religious backgrounds, with most of them being Muslims, Christians, Jews and also non-religious people.

- Ibn Sina, often known in the West as Avicenna, was a Persian polymath who is regarded as one of the most significant physicians, astronomers, thinkers and writers of the Islamic Golden Age, and the father of early modern medicine.
- Avicenna, of the 10th and 11th centuries, has an important place in the history of medicine in Iran and the world.
- The term 'Islam' refers to the Islamic religion and the Islamic civilization which developed around the religion. Islamic civilization comprises of several cultures and faiths, even though, the proportion of Muslims among its population has increased significantly over time.
- The Islamic history, known as High Caliphate, was significantly developed between the phase of the Umayyad Caliphate and the early phase of Abbasid Caliphate.
- The religious scholars of Islam comprised of both men and women, and were collectively known as the *ulama*. These scholars were very influential in the Islamic society, particularly in the fields of Sharia law, speculative thought and theology.
- One of the major merits of the Islamic Golden Age was its contribution to the field of medicine. From physiology to human anatomy, from surgery to drugs, treatment and other branches of medicine, several major innovations were made during the Islamic Golden Age.
- The domain of medicinal drugs also witnessed major contribution during the Islamic Golden Age. Physicians of this era emphasized the use of natural substances and plants for treatment.
- Medieval Islamic society attempted at curing patients through the process of anaesthesia and antisepsis. Before these procedures were developed, surgery was limited to fractures, dislocations, traumatic injuries resulting in amputation, and urinary disorders and so on.
- Cosmology in Islamic society is mainly derived from various sources including the Quran, Hadith, Sunnah, and current Islamic as well as other pre-Islamic sources.

2.6 KEY WORDS

- **First Punic War:** It was fought between Carthage and Rome between 264 and 241 BCE, largely over control of Sicily.
- **Aqueduct:** It is a navigable channel constructed to supply water.
- **Polymath:** This term refers to a person who possesses knowledge of various disciplines.

- **Equatorium:** It is an astronomical instrument used to determine the position of the moon, the sun and planets. It requires no calculations or geometric models to locate a celestial body's mean and anomalistic position.
- **Cauterization:** It is the method which involved burning the skin or flesh of a wound, performed in order to stop bleeding and prevent infection.

2.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Write a short note on the Roman scientific and technological achievements revived in the 19th and 20th centuries.
2. Briefly mention the contribution of Ptolemy during the Roman period.
3. What was Galen's contribution to medicine?

Long-Answer Questions

1. Examine the significant contribution of Avicenna in the field of medicine in Iran and the rest of the world.
2. Discuss the major Islamic scientific achievements.
3. 'One of the major merits of the Islamic Golden Age was its contribution to the field of medicine.' Elucidate the statement.

2.8 FURTHER READINGS

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UNIT 3 LEGACY OF INDIAN SCIENCE

NOTES

Structure

3.0 INTRODUCTION

A study of the scientific achievements that have taken place in the Indian subcontinent will certainly surprise and perhaps entertain most individuals. Surprised by the relevance of scientific discovery made by the Hindu, Islamic, and Buddhist philosophers to their everyday lives; they sometimes, raise their eyebrows as they learn about the unique ideas that developed in a dynamic culture with many languages and religious perspectives. Many scientific discoveries attributed to the European origin actually came from India through the Arab translators. Other ideas, such as how to prevent some plant diseases with boiled milk, had little influence on scientific thought beyond the local region, yet they are unique and quite interesting.

Aryabhatta, Varahmihir and Bhaskara I were the great mathematicians and astronomers in the Gupta and Post-Gupta periods. The mathematical and astronomical works of Aryabhatta and Varahmihir appear to be of such range and richness that Bhaskara I considered that their achievements could only be attributed to divine gifts beyond the reach of sense. Aryabhatta was a pioneer of his time. Future astronomers and mathematicians like Varahamihira, Bhaskara I and Brahmagupta have acknowledged it. Laying the foundations of Indian astronomical knowledge was a singular contribution of the Arybhattan school. The route by which it was transmitted to India and outside, needs a thorough and systematic study. In this unit, we will

discuss the legacy of Indian science by considering the contribution of Aryabhata, Varahamihira and Bhaskara I. It will also focus on the science and technology in China

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3.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the significant developments witnessed in the field of science and technology in the ancient India
- Discuss the major contribution of Aryabhatt, Varahamihira and Bhaskara I
- Describe the major scientific and technological advancements witnessed in the Classical Age in China

3.2 SCIENCE AND TECHNOLOGY IN THE GUPTA PERIOD

India witnessed extensive achievements in science and technology under the Gupta Empire. The highlights of this era were accomplishments in dialectics, literature, logic, mathematics, astronomy, engineering, art, religion and philosophy.

The Guptas emerged as the paramount power in India, in the AD 4th century. With the advent of the Guptas, the period of confusion, conflict and disintegration came to a halt and India became politically united. The Guptas ushered a new era in the history of India. Their rule lasted for more than two centuries. Several powerful and benevolent Gupta rulers infused new hope in the Indian civilization and the country developed in all spheres of life. The benevolent Gupta rulers took keen interest in the development of art, architecture, science, technology, education, literature, philosophy and other areas.

The advancement of science and technology was the most notable feature of this period. Due to the patronization of the Gupta rulers, the country produced outstanding scholars of repute in various fields like education, science and technology, art and architecture and so forth. They rose to the pinnacle of their heights during this period. So, the Gupta period is also known as the Classical Age or the Golden Age of ancient India.

Like several other fields, the field of science and technology made tremendous progress during the Gupta period. Many scholars of science, astronomy, astrology, medicine, metallurgy and geometry emerged during the Gupta period and they contributed immensely to the development of science and technology of this age.

3.2.1 Astronomy and Mathematics: Aryabhatt, Varahamihira and Bhaskara I

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The great scholars of the period not only occupied a high place in the history of India, but also of the whole world. Their researches in mathematics and astronomy guided scientists in other countries for centuries, which exercised a direct influence on scientific thought in Arabia and other central Asian countries and indirectly influenced the European countries.

Aryabhatta

Among the notable astronomers and mathematicians of the Gupta age, Aryabhatta (AD 476-550) has been accepted as the most prominent one. A few of his works such as *Aryabhatiyam*, *Dasagitikasutra* and *Aryashtasata* are accessible to us. He was the first to treat mathematics as a distinct subject of science. His most prominent achievement was the discovery of the principals of the place value of the first 9 numbers and the use of 'zero', which simplified arithmetic calculations and brought a revolution in this field. He gave a value for 'pie', 3.1416, more accurate than any one suggested before him. He also calculated the length of the solar year to 365.3586805 days. It is remarkably close to the recent estimates.

It was largely due to his efforts that astronomy was recognized as a separate discipline from mathematics. He was the first Indian astronomer to declare that the Earth was a sphere, which revolves round the sun and rotates round its axis. He was also the first Indian scientist who described the true causes of solar and lunar eclipses and the method of calculating them precisely. His calculation of the size of earth is very near to that estimated by modern astronomers.

Aryabhatta's contributions lie in the areas of (i) astronomy (ii) questions of time reckoning (iii) spherical geometry and trigonometry. Two of the most important results that appear in the *Aryabhatiyam* pertain to (i) the value of ð (the ratio between the circumference and diameter of a circle) and (ii) the Rsine tables.

Among his writings, the *Aryabhatiyam* became the most famous, in which he found solutions to many problems of algebra, geometry, trigonometry and others. It is also believed that the decimal system was discovered during this period, either by Aryabhatta or by Varahmihira, as both of them have described it in their works. Due to these great scientific discoveries, Aryabhatta has been deservedly called the father of the astronomical science in India.

Varahmihira

Varahmihira (AD 505-587) was second only to Aryabhatta in Indian astronomy. His work on astrology, the *Brihatsamhita* is an encyclopaedia of information in various branches of knowledge. This book has 106 chapters and hence this book is also called 'great compilation'. This book is all about divination. He has even

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written about other topics like astronomy, clouds, planetary movements, rainfall, eclipses, growth of crops, matrimony, gems, pearls, architecture, manufacture of perfume, domestic relations and rituals. *Brihatsamhita,* is a compendium of all available knowledge on technical sciences like architecture, metallurgy, physiognomy and so forth. Varahmihira was a man of such a comprehensive intellect that there was hardly any branch of natural sciences to which he did not contribute.

Among his other writings, the *Panchsiddhantika*, the *Brahmajataka* and the *Laghujataka* are noteworthy.

In his *Panchsiddhantika,* he has written about mathematical astronomy. He explains about the five earlier astronomical treatises by five authors, namely the PaulisaSiddhanta, PaitamahaSiddhanta, Surya Siddhanta, VasishthaSiddhanta and RomakaSiddhanta.

Varahmihir's contributions in the field of mathematics are as follows:

- Sine tables were created by Aryabhatta but were improved by Varahamihira.
- He discovered a version of Pascal's triangle.
- He created the first 4×4 magic square.
- He used it to calculate the binomial coefficients.

Bhaskara I

Bhâskara (AD 600 – 680) (commonly called Bhaskara I to avoid confusion with the 12th-century mathematician Bhâskara II) was a 7th century mathematician, who was the first to write numbers in the Hindu decimal system with a circle for the zero, and who gave a unique and remarkable rational approximation of the sine function in his commentary on Aryabhata's work. This commentary, *Âryabhamîyabhâcya*, written in 629 CE, is among the oldest known prose works in Sanskrit on mathematics and astronomy.

He wrote commentaries on the writings of Aryabhatta and several other independent works too. Among his writings, the *Mahabhaskarya*, the *Laghubhaskarya* and the *Bhasya* were well-known. Some other scholar, like Lata, Pradyumna and Vijayanandin, contributed further to what Aryabhatta did and ultimately Varahmihira took all that to the peak.

Bhaskara's probably most important mathematical contribution concerns the representation of numbers in a positional system. The first positional representations had been known to Indian astronomers approximately 500 years prior to this work. However, these numbers, prior to Bhaskara, were written not in figures but in words or allegories and were organized in verses. For instance, the number 1 was given as moon, since it exists only once; the number 2 was represented by wings, twins, or eyes since they always occur in pairs; the number 5 was given by the (5) senses. Similar to our current decimal system, these words were aligned such that each

number assigns the factor of the power of ten correspondings to its position, only in reverse order: the higher powers were right from the lower ones.

3.2.2 Medicine

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General medicine, along with veterinary and Ayurvedic medicine, made enormous advancement during the Gupta period. The Indian surgeons were well-versed in the art of dissection, plastic surgery, veterinary surgery and even in special branches of surgery as that of eye, ear and nose. Bone-setting reached a high degree of skill and plastic surgery developed far beyond anything known elsewhere at that time. In this respect, Indian surgery remained well ahead of Europe until the 18th century. Though Indian doctors conceived the existence of microscopic forms of life very early, it was never realized that this might cause diseases. However, the physicians knew the symptoms of many diseases. Vagabhata was the eminent writer of medical sciences during those times. He wrote *Astanga-sangrah,* which is a systematic summary of *Charaksamhita* and *Susrutasamhita.*

The knowledge of medical science, which progressed during this period, was available to young men of all castes. Takshashila was the centre of advanced learning of medical sciences of the period. The study of medical sciences in this age comprised diverse aspects, such as pathology, medicine, surgery, toxicology, blood test, study of bones and others.

The whole science was divided into two parts — *Shastra* (theory) and *Prayoga* (practice). The student of medicine was required to acquire proficiency in both these aspects. At that time, great emphasis was given on the treatment of *Shalya* (surgery). Though students received instructions in surgery and medicine from individual teachers, there were institutions with important hospitals attached to them for practical training. In ancient India, the surgeons and physicians had a very high standard of knowledge and their fame spread even to distant foreign countries. In the 8th century, the Khalifa of Arabia had invited physicians to teach medical sciences in state hospitals. Khalifa Harun also sent several scholars to India to study Hindu medicine and pharmacology and induced about 20 doctors to come to Baghdad to become chief medical officers of state hospitals and to translate ancient Indian Sanskrit medical works into Arabic. Most celebrated among them was Manaka (Manikya), who was originally invited to cure an ailment of Sultan Harun, who challenged the skill of Arabic physicians. He succeeded in his treatment and later took up the post of the director of state hospitals and translated the work of *Susruta* into Arabic.

3.2.3 Veterinary Science

Along with medicine, veterinary science also progressed considerably during that period. However, veterinary science had been developed in India much before the Gupta period. During Gupta period, it got proper attention from researchers.

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Since animals were regarded as a part of the same cosmos as humans, it is not surprising that animal life was keenly protected and veterinary medicine was a distinct branch of science with its own hospitals and scholars. Salihotra was a great scholar of this science. It is also believed that the two Pandava brothers, Nakula and Sahdeva, were experts in the diseases of horses and their cure.

During that period, Palakapya wrote *HastyAyurveda* (The Science of Prolonging Elephant Life), a treatise on the diseases peculiar to elephants and their treatment. *Asvasastra* was another great work in the field of medical science and it was a treatise on the diseases of animals, which proved that veterinary science progressed tremendously during the Gupta period. However, some historians believe that during the Gupta age, there were no regular veterinary institutions to impart education. Probably students learned it from the experts of veterinary science. According to Stanley Wolpert:

> Veterinary science had developed into an Indian medical specialty by that early era and India's monarchs seemed to have supported special hospitals for their horses as well as their elephants. Hindu faith in the sacrosanctity of animals as well as human souls and belief in the partial divinity of cows and elephants, helped explain perhaps what seems to be far better than lavish of such animals.

3.2.4 Ayurveda

The knowledge of Ayurveda flourished during this period, which is still practised by present-day physicians. The basic concept of Indian medicine was believed to be humour (*dosha*). Most ayurvedic practices taught that health was maintained through the even balance of three vital fluids of the body wind, gall and mucus. The following five winds (*Vayu*) maintained bodily functions:

(i) *Udana* (emanating from the throat and causing speech)

(ii) *Prana* (in the heart and responsible for breathing and swallowing of food)

(iii) *Samana* (fanning the fire in the stomach, which cooks and digests food and divides it into digestible and indigestible parts)

(iv) *Apana* (in the abdomen and responsible for excretion and procreation)

(v) *Vyana* (a generally defused wind causing the motion of the blood and the body)

3.2.5 Metallurgy, Chemistry and Physics

Metallurgy, chemistry and physics also flourished during the Gupta period. Unfortunately, no books on these subjects have been discovered, but there is absolutely no doubt that metallurgy and chemistry made remarkable progress during the Gupta period. The famous Iron pillar near Qutab Minar in Delhi belongs to this age. This Iron pillar is a living example of the progress made in the field of metallurgy during the period. This huge pillar, made of iron, is 24 feet high and weighs seven

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and half tonnes. It was so skillfully manufactured that in spite of its exposure for centuries to sun and rain, it shows no sign of rusting and corrosion, which is surprising to even modern metallurgists as to how it was prepared. This is the best proof of the progress made in the field of metallurgy during the period. The discovery of several gigantic copper statutes of Buddha also represent the advanced metallurgical skill of the Gupta age.

During this period, the use of mercury and iron with proper treatment for the preparation of medicines was prevalent. Writers like Varahamihira have mentioned this in their treatises. The close association of medicine and chemistry, which was to achieve great progress in the later period, began during the Gupta period. Nagarjuna, the famous Buddhist scholar, was also a great scholar of medicine, chemistry and metallurgy. He discovered many new medicines.

Thus, the Gupta age witnessed the highest progress in the field of science in general and astronomy and medicine in particular. It was an age of intellectualism, which led to remarkable progress, new inventions and innovations in every field of learning and specifically in the field of sciences.

Check Your Progress

1. Why is the Gupta period also known as the Classical Age or the Golden Age of ancient India?
2. Mention some of the significant discoveries made by Aryabhatta.
3. Who is known as the father of the astronomical science in India?
4. What are the five winds (*Vayu*) which maintain proper body functions as per Ayurveda?

3.3 SCIENCE AND TECHNOLOGY IN CHINA

Significant technical advances in various fields occurred during the Classical Age. These new developments in technology were largely responsible for the transformation of China into a centralized, well-organized state by 221 BC. They provided an economic capability that ensured China could maintain its civilization entirely independent of other parts of the Ancient World, thus, preserving the cultural pattern they had helped create. The improvements were in building, communications, hydraulics and metallurgy.

3.3.1 Town Planning and Building Technology

Behind the town planning of Han cities was a set of ancient ideas and practices, which can be termed feng-shui, or 'wind and water'. The initial setting of a settlement involved complex calculations by geomancers, whose occult and practical knowledge ensured that evil spirits or influences would not trouble the inhabitants.

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The Chinese chose to ally themselves with Nature rather than oppose it. A square, the basic shape of the classical settlement, found a parallel in the belief that heaven was round and the earth was square in shape. But in terms of everyday life, the people who lived in towns were effectively under the control of the authorities. The rigidity of the Han town planning was relaxed later, as a result of population expansion, less centralized regimes, the growth of commercial activity and the enforced movement of large numbers to less typically Chinese cities in the south through the barbarian invasions of the north. Nevertheless, the cities in China have never been centres of social change. Unlike those in the West, they did not develop wealth through trade and industry; their independence was never sufficient to reject established political, legal and religious ideals. As university centres, they have acted to support centralization by preparing students for entry examinations to the civil service. The shang has never become a socially significant class because the Chinese town was not a spontaneous accumulation of population, neither of capital nor facilities of production, nor was it only essentially a market-centre. It was above all a political nucleus, a node in the administrative network, and the seat of the bureaucrat who had replaced the ancient feudal lord. The architecture was enhanced by a lavish use of colour, not only in roof tiles, but on painted columns, lintels and beams, richly bracketed cornices, and broad expanses of plastered walls. In architecture the Chinese were noteworthy. Partly, because wood was so extensively used in buildings and partly because of the wars which have swept the land, not many examples of early architecture have come down to us. However, the China of the 19th and mid-20th centuries abounded in structures of many kinds, many of which had been erected during the Ming and few of which were of earlier dynasties.

The building technology was concerned primarily with the construction of walls. The ubiquity of walls in Chinese civilization has often been remarked. Every Chinese city had its surrounding wall, whilst there was hardly a village of any size in northern China which had not at least a mud wall around its huts and stables. Within the city itself, walls divided the dwelling areas into lots and compounds, sections and districts. Gates, sometimes set in large watch towers, controlled the means of access from one part to another. Cities were planned and the arrangement of walls reinforced the power of the authorities — the prince and his officials. The chief method of wall construction was tamped or rammed earth. Wooden shuttering was used, dry earth being rammed inside until solid. Then, the shuttering would be removed and the process repeated at a higher level. Bamboo might be placed between each layer to absorb moisture. Earth walls probably determined the two most characteristic features of Chinese architecture, namely that walls were not in general weight-bearing, and that buildings were furnished with generously overhanging eaves. During the Ch'unCh'iu period, sun-dried bricks were added as a facing for 'earth' walls, and by the end of the Warring States period fire-baked bricks, sometimes highly ornamented, had become available.

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Archaeological discoveries at the Ch'in capital have revealed water-conduits of thick stoneware. When the ancient Asian nomads surrounded their camps with a rampart of earth, it is not surprising that the agrarian culture of China erected walls around its earliest cities. The rural landscape was dominated by the walled city, which contained the state granaries that held the grain-tribute or tax upon which organized government depended. This food surplus maintained the army and the conscripted labour force involved in water-conservancy schemes. As canals and irrigation projects became more complex and more general, particularly from the Han Empire onwards, the walled-city-in-the-country was the effective seat of government and administration. Night soil being the chief fertilizer in China, it was inevitable that intensive agriculture developed in the fields just outside the walls of cities. Shang cities possessed extensive fortifications. Those of Ao, due south of Anyang, almost twenty metres wide at the base, enclosed an area of 1,756 square metres. Impetus for advancement in the art of fortification came from the collapse of Chou power and the deadly rivalry between the Warring States. City walls were enlarged and strengthened against such devices as tunnels and the diversion of rivers to weaken their foundations. Other military walls were those constructed along state frontiers, especially in the north where the Chinese were reaching lands unsuited to settled agriculture. Here was a cleavage between two environments, the lands of the steppe and the lands of the sown. The various walls built by the Warring States were eventually linked by the First Emperor to form the Great Wall, which was intended to thwart potential cavalry attacks by nomads. The Great Wall is well over three thousand kilometres long and it is thought the only work of man which could be picked out by Martian astronomers. There can be no doubt concerning the superiority of ancient Chinese roads to Roman ones. The Temple of Heaven in Peking dates from the Ming dynasty. This magnificent building embodies perfectly the formal grandeur of Confucian philosophy.

3.3.2 Transportation and Forms of Communication

Commerce was dependent upon means of transportation. Often, these were very imperfect. Rivers, especially the Yangtze and its major tributaries, fortunately afforded access to much of the country and were plied by different kinds of craft. Rivers were supplemented by canals, notably the Grand Canal. In the north, the roads were of the sort that could be traversed by carts and wheelbarrows. Donkeys and camels were also employed for trade with Mongolia. In the Yangtze Valley and the south, the typical road could be used only by the wheelbarrow or the coolie, who transported freight by means of a carrying-pole balanced on his shoulders. Travel was either on foot, by horseback, or in a sedan chair. All transportation was slow, and land transportation was also costly. Conditions were probably no worse than in the West before the advent of the steamship and the railroad, but time-distances was vast and even internal commerce was handicapped.

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Whereas the Roman road might be described as a heavy wall laid on its side, the Chou road was essentially a thin, convex, watertight 'shell', resting on ordinary subsoil. In this use of a light and elastic road surface the Chinese avoided the problems of temperature change and anticipated the technique of John McAdam by two millennia. During the Warring States period there was much road-building activity both for military and commercial purposes. A factor in the success of Ch'in may have been its development of communication, road and canal. In a debate about policy Ts'aiTse told the Marquis Ying, the chief minister, that he had heard of his plans which would control the Lords from where he sits, would direct wealth from the land of Three Rivers so that it bears fruit in Yi-yang, would seal off the way through Sheepgut Canyons, garrison the mouth of the Great Highroad, cut off Fan and Chung-hang's tail and build a long and trestled roadway to Shu-Han so that all the world may fear Ch'in'.

The economic importance of Shu and Pa as the source of iron led to the construction of the several roads from the Ch'in heartland. A southern extension was the famous 'Five-Foot Way', built by the First Emperor. This road ran from Shu to Yeh-yu, near Kunming Lakes, and for many miles there were 'hanging galleries', suspended along the sides of precipitous slopes. The 'hanging galleries' were wooden balconies jutting out from the facade; they carried a road about five meters wide. Along its route there were a variety of bridges, though records exist of more than one bridge over a thousand feet in length, with nearly seventy spans, in the Wei valley. The simple wooden beam bridge had been extended into a trestle structure, resting on piers close to the water-level and likely to disappear from sight at flood seasons. Boat bridges were also in use as well as simple stone arch bridges.

The imperial post-station system was started under the Chou kings. Messengers, coachmen and station-masters were maintained by the states in order to improve communication. Diplomatic missions sent out by the state of Lu increased from 179 kilometres per mission in the late 8th century to 726 kilometres per mission in the late 6th century. Improved vehicles facilitated easy travel. The Shang had chariots with solid wheels, but in the Warring States period these cumbersome wheels gave place to more efficient ones, with a hub, spokes and a rim. An efficient equine harness originated in China at this time too. Unlike the throat-and-girth harness of the Ancient World down to the end of the Roman Empire, the Chinese trace harness and the later, improved collar harness did not choke the horse and so reduced its tractive power by about one-third. Heavy carts, with strengthened wheels and axles, were becoming common at the end of the Classical Age. These vehicles and boats carried goods, grain and military supplies, though water transport was to assume chief importance after the Han Empire.

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Navigation was appreciated early in China. The great mechanical advantage which canals offer for the transportation of heavy goods, anticipating the canal building era that accompanied the Industrial Revolution in the West by eighteen centuries, was realized during the Warring States period. In 486 BC the Prince of Wu ordered the construction of the Han Kou Canal, which connected the Huai River with the Yang-tze. His objectives were military; he wanted a means of supplying Wu troops attacking Sung and Lu to the north. This canal — the first practical inland artificial waterway in human history now forms a section of the Grand Canal, linking Hangchow with Beijing, the oldest summit canal in any civilization (13th century). Hydraulic engineering, we have already noticed, has been crucial to Chinese civilization. Of all the countries in the world China's control and use of water has been outstanding. The environment permitted irrigation on a small scale and then encouraged not only irrigation but the schemes of drainage and flood prevention on an increasingly larger scale. It should be remembered that Yu the Great Engineer is connected with the origins of feudalism. He founded the Hsia dynasty after organizing the people into a labour force capable of controlling the waters. The corvee system of labour provided the manpower required for hydraulic engineering, a vast supply of labour unavailable in primitive collectivist society. In the long term, of course, irrigation schemes and the construction of artificial waterways undermined the feudal system. The great Chengkuo project only served to increase the central authority of the Ch'in state, but this process of centralization was only completed in 221 BC. Prince Huan of Ch'i is supposed to have thrown up dykes along the lower reaches of the Yellow River, thereby concentrating the nine streams of the previous delta into one. This early experiment failed (before 600 BC). The load of silt carried annually by the Yellow River is 1,000,000,000 tonnes, much of which is deposited in its own bed on the flood plain. The continuous elevation of the river makes it very vulnerable to changes in course and flooding when its banks burst. Therefore, Yu had caused the channels and canals to be dug and deepened and Li Ping, the Ch'in engineer, adopted the motto, 'Dig the channel deep, and keep the dykes low'. Because of the size and variation in the flow of China's rivers the usual policy of hydraulics was cooperation with Nature rather than any attempt to contain the rush of water.

The triumph of Ch'in was intimately bound up with technical advance. Although the First Emperor had supported large-scale schemes before his conquest of all the Warring States, they were a matter of urgent necessity after 221 BC. He was left with an enormous army, besides countless prisoners. In order to occupy these idle hands and break up what remained of the previous social structure, the Ch'in Emperor undertook the construction of the Great Wall, the imperial road network, and strategic canals, like the Kuahsien system in the Ordos (215 BC) and the Magic Canal, which joined the Yang-tze to the West River and opened up the far south (219 BC).

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3.3.3 Mining and Metallurgy

The Chinese did not engage extensively in mining. However, they utilized by simple processes the widely scattered deposits of iron. They began early to burn the coal with which parts of the country were so well supplied. They made use of copper and a little gold and silver. There was the revolution in metal working. Although bronze reached China as late as 1500 BC, the Chinese attained a far higher level of technique than other bronze users. The advanced kilns of the native ceramics, industry must have played an important part in this development, just as they facilitated the unprecedented leap forward in iron metallurgy during the period of the Warring States. There are references to sophisticated iron-casting in Ch'i (before 600 BC) and in Wu (before 500 BC), but archaeology points to the 6th century, when the use of iron probably permeated eastwards via the passes of the Tarim Basin. This could account for the state iron industries in Ch'in, though the rich deposits of iron ore in Shu and Pa must have also contributed to such a decisive advance. Iron weapons, or bronze weapons with iron cores, partially explain some of the crushing defeats that Ch'in armies inflicted on their opponents. In agriculture, the growth of irrigation schemes, the use of oxen to pull the plough, the improved calendar and the increasing application of animal and human fertilizer, combined with the introduction of iron implements to cause a revolutionary growth in the productivity of labour. The population of China may have grown five-fold to around fifty million in the Classical Age, an upsurge that was supported by better agricultural methods as much as by an extension of the area of cultivation. Iron was used for tools, weapons and moulds for casting. Most important of all is the fact that iron-casting was practiced almost as soon as iron was known. In the West, iron metallurgy was to be limited to the forge until 1350. Steel could have been produced during the period of the Warring States, but the earliest archaeological evidence so far indicates the end of the Han Empire. Possible reasons for this amazing progress in iron and steel technology include the high phosphorus content of Chinese iron ores, which have a low melting-point; good refractory clays, permitting the construction of adequate blast furnaces and crucibles; the invention of the double-acting piston bellows, which gave a strong and continuous blast for furnaces, thus keeping temperatures high; the application of water-power to these bellows during the Han Empire; the use of coal for making very hot piles around crucibles, not later than the 4th century; and the expertise derived from the pottery and bronze industries.

3.3.4 Industry, Astronomy and Other Accomplishments

Due to the fundamental role of Nature in early Chinese civilization —that ancient intimacy of man and environment which found philosophical expression in the Yin-Yang theory—specialists such as astronomers, astrologers, engineers and magicians were absorbed in the central bureaucracy. Science and sorcery were able to coexist

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together because of the old idea that natural phenomena, like flooding, earthquakes or eclipses, were connected with supernatural powers. The benevolence of Shang Ti was entreated by the sacrifices of the priest-king; hence, the attention paid to astronomy, whose predictive function in respect of heavenly movements was regarded as a state secret. An imperial edict of the later T'ang dynasty indicates the security-mindedness of the throne in 840. The officials in the imperial observatory were addressed thus:

> If we hear of any intercourse between the astronomical officials or their subordinates and officials of other government departments or miscellaneous common people, it will be regarded as a violation of security regulations which should be strictly adhered to. From now onwards, therefore, the astronomical officials are on no account to mix with civil servants and common people in general.

Chinese astronomers have amassed long series of observations on things which were not studied elsewhere, for example novae and supernovae, so important in current cosmological speculation. A Shang oracle-bone of 1300 BC bears the oldest record of a nova in any civilization. Systematic records of sun-spots were kept from 28 BC; imperial astronomers must have observed through thin slices of jade or some similar. Water-powered trip hammers just one invention that aided the improvement of agricultural techniques on the large estates.

Possibly, the chief task of the Bureau of Astronomy was the regulation of the calendar. Not only did the agricultural cycle depend upon its accuracy but even more it was an immemorial custom that acceptance of the calendar promulgated by a ruler was a symbol of submission on the part of the subject. The lack of an accurate calendar could prove a tactical disadvantage for a rebel leader because celestial portents were liable to political interpretation. Four Han officials handled the sensitive area of 'explaining' natural phenomena: they were the Imperial Astronomer, who attended to observations and the calendar; the Imperial Astrologer, whose task was observation and the prediction of fortune; the Imperial Meteorologist, who dealt with the weather conditions, records of which have also been found on Shang oracle-bones; and the Imperial Clock Official, who was charged with the supervision of clepsydras, or water clocks.

It should not be surprising to learn that inventors and scientists in Chinese civilization were even members of the ruling classes, either heads of bureaus or minor officials; otherwise, they tended to be kung or near-slaves in government employment. Chang Heng (78-139) was an inventor, mathematician, astronomer, cartographer and poet. His seismograph was one of the wonders of the imperial observatory, which he ran at the Imperial Astronomer. It could locate earth tremors at a distance of several hundred miles. North China was subject to earthquakes from earliest times; Loyang suffered considerable damage in 133 and 135. Chang Heng's 'earthquake weathercock', as it was called, could not furnish a scientific explanation of seismic disturbance, but it did give the One Man immediate notice

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of a natural disaster. Other inventions to his credit were an improved armillary sphere to trace the paths of planets and the first known application of motive power to the rotation of astronomical instruments. Although astronomy was an 'official' science and its study was a concern of the civil service, no lack of speculation about the nature of the universe existed among contemporary philosophers. A strikingly modern point of view was known as the HsuanYeh, or 'Infinite Empty Space Teaching'. Here, is an account of its later spokesman, Ch'iMeng:

The books of the HsuanYeh School were all lost, but Ch'iMeng, one of the librarians, remembered what its masters before his time had taught concerning it. They said that the heavens were empty and void of substance. 'When we look up at it we can see that it is immensely high and far away, having no bounds. . . . The sun, the moon, and the company of stars float in the empty span moving or standing still. All are condensed vapour. . . .'

Later in the Han dynasty, China made a number of significant technical advances, accumulated information, formulated some fundamental principles of science and anticipated many discoveries traditionally attributed to the West. Until the early 20th century, it has been fashionable to refer to Chinese civilization as other-weirdly, unscientific and anti-technological. At hem, it has been hinted the Chinese were practical rather than theoretical.

A high provincial official, Tu Shih, introduced a water-powered metallurgical blowing-engine in AD 31. The continuous blast thus afforded was of inestimable value to the state-owned iron industry and may have led directly to the production of steel. From this time onwards, there is mention of 'the harmony of the hard and the soft', which could mean steel made by a 'co-fusion' process; that is, 'the piling up together and heating of billets of wrought iron and cast iron, with the object of obtaining a material, steel, which we now know has an intermediate carbon content. But there is no doubt that steel was being produced during the 6th century by a method that foreshadowed the Siemens-Martin process of combining cast and wrought iron. Another invention of the imperial workshops was paper-making, announced in 105 by the director, Ts'ai Lung, who was a eunuch. Previous to this appointment, he had been confidential secretary to the emperor. Paper, when combined with block-printing in the T'ang Empire, brought about a revolution in communication. The earliest known printed book, the *Diamond Sutra*, dates from AD 868 and was found in the immense complex of Buddhist temple-caves at Tun-huang. Older than this scroll is a block-printed Buddhist charm (AD 770). The advance in printing came from the fusion of two skills; for centuries the Chinese had used ink and paper besides being expert in stone engraving. During the early part of the 10th century block-printed editions of the Classical Books became generally available. To be a Chinese came to mean belonging to a great cultural tradition as well as to an Empire. Paper-making assisted the spreading of hygienic

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habits throughout the society too. Before the T'ang dynasty, the use of paper in lavatories was general.

The state-controlled salt industry was able to exploit wells in Szechuan from the Former Han dynasty. Deep bore-holes were achieved with iron or steel bits; extraction of underground brine was permitted to a depth of 2,000 feet. A long bamboo tube with a valve was sent down as a bucket, and the raised brine evaporated in large iron pans, with the aid of natural gas collected from other bore-holes. The ability to tap this source of salt so far from the sea has been invaluable in times of national crisis, the last such occasion being the Japanese invasion during World War II. An advantage for early Chinese technology was the abundance of natural piping in the form of bamboo. Besides its usefulness in salt mining, split bamboos and wooden constructions could be arranged as irrigation flumes, thereby providing a means of overcoming unsatisfactory surfaces for water. Such technical advances in hydraulic engineering were to be expected, given the age-old connection between centralized government and 'water benefits'. But irrigation, though important, had to share its prominence with an unceasing struggle for river-control and a constant preoccupation with inland water transport. Grain-tribute was the fundamental source of supply for the centralized state. Emperor Han Wu-ti had the Ch'ang-an Canal cut in 131-129 BC in order to connect the capital with the lower Yellow River; for the systematic transportation of heavy goods.

A nautical invention of supreme interest was the stern-post rudder, whose prototype has been discovered in a pottery model of a ship lately recovered from a Former Han tomb. The steering oar, general in the West until the 13th century, put a severe limitation on the size of vessel that could be safely constructed, besides giving the steersman a hazardous task of control in stormy seas. The development of the stern-post rudder and the watertight compartment allowed junks to become large deep-ocean craft. The Ming fleet that was to cruise down the eastern coast of Africa under Admiral Cheng Ho, nearly 60 years before Vasco da Gama rounded the Cape of Good Hope in 1497, comprised vessels of more than 1,500 tonnes. The Portuguese ships of da Gama did not exceed 300 tonnes fully laden.

On land, several technical advances in transportation deserve attention. First, the wheelbarrow is reputed to have been invented by a Shu general in the Three Kingdoms period, but it seems likely that the 'wooden ox' was known in the Later Han dynasty, over eleven centuries before it reached Europe. In China, labour-saving devices have never been rejected because of the fear of technological unemployment. A second improvement concerned the equine harness, now transformed into the highly efficient collar harness. This further advance on the Warring States model increased effective traction enormously. The Chinese wagon was much larger than its counterpart in other parts of the world till the Middle Ages in the West.

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Check Your Progress

5. Who was Chang Heng?
6. Name the chief fertilizer used in China.
7. Which ruler ordered the construction of the Han Kou Canal? What was its objective?

3.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The advancement of science and technology was the most notable feature of this period. Due to the patronization of the Gupta rulers, the country produced outstanding scholars of repute in various fields like education, science and technology, art and architecture and so forth. They rose to the pinnacle of their heights during this period. So, the Gupta period is also known as the Classical Age or the Golden Age of ancient India.
2. Aryabhatta was the first to treat mathematics as a distinct subject of science. His most prominent achievement was the discovery of the principals of the place value of the first 9 numbers and the use of 'zero', which simplified arithmetic calculations and brought a revolution in this field. He gave a value for 'pie', 3.1416, more accurate than any one suggested before him. He also calculated the length of the solar year to 365.3586805 days.
3. Aryabhatta is known as the father of the astronomical science in India.
4. The following five winds (*Vayu*) maintained bodily functions:
   (*i*) *Udana* (emanating from the throat and causing speech)
   (*ii*) *Prana* (in the heart and responsible for breathing and swallowing of food)
   (*iii*) *Samana* (fanning the fire in the stomach, which cooks and digests food and divides it into digestible and indigestible parts)
   (*iv*) *Apana* (in the abdomen and responsible for excretion and procreation)
   (*v*) *Vyana* (a generally defused wind causing the motion of the blood and the body)
5. Chang Heng (78-139) was an inventor, mathematician, astronomer, cartographer and poet. His seismograph was one of the wonders of the imperial observatory, which he ran at the Imperial Astronomer. It could locate earth tremors at a distance of several hundred miles.
6. Night soil was the chief fertilizer used in China.

7. In 486 BC the Prince of Wu ordered the construction of the Han Kou Canal, which connected the Huai River with the Yang-tze. His objectives were military; he wanted a means of supplying Wu troops attacking Sung and Lu to the north.

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3.5 SUMMARY

- India witnessed extensive achievements in science and technology under the Gupta Empire. The highlights of this era were accomplishments in dialectics, literature, logic, mathematics, astronomy, engineering, art, religion and philosophy.
- Like several other fields, the field of science and technology made tremendous progress during the Gupta period. Many scholars of science, astronomy, astrology, medicine, metallurgy and geometry emerged during the Gupta period and they contributed immensely to the development of science and technology of this age.
- Among the notable astronomers and mathematicians of the Gupta age, Aryabhatta (AD 476-550) has been accepted as the most prominent one. A few of his works such as *Aryabhatiyam*, *Dasagitikasutra* and *Aryashtasata* are accessible to us.
- Varahmihira (AD 505-587) was second only to Aryabhatta in Indian astronomy. His work on astrology, the *Brihatsamhita* is an encyclopaedia of information in various branches of knowledge.
- Bhâskara (AD 600 – 680) was a 7th century mathematician, who was the first to write numbers in the Hindu decimal system with a circle for the zero, and who gave a unique and remarkable rational approximation of the sine function in his commentary on Aryabhata's work.
- General medicine, along with veterinary and Ayurvedic medicine, made enormous advancement during the Gupta period. The Indian surgeons were well-versed in the art of dissection, plastic surgery, veterinary surgery and even in special branches of surgery as that of eye, ear and nose.
- Along with medicine, veterinary science also progressed considerably during that period. However, veterinary science had been developed in India much before the Gupta period. During Gupta period, it got proper attention from researchers.
- The basic concept of Indian medicine was believed to be humour (*dosha*). Most ayurvedic practices taught that health was maintained through the even balance of three vital fluids of the body wind, gall and mucus.

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- Metallurgy, chemistry and physics also flourished during the Gupta period. Unfortunately, no books on these subjects have been discovered, but there is absolutely no doubt that metallurgy and chemistry made remarkable progress during the Gupta period.
- Significant technical advances in various fields occurred during the Classical Age. These new developments in technology were largely responsible for the transformation of China into a centralized, well-organized state by 221 BC.
- The building technology was concerned primarily with the construction of walls. The ubiquity of walls in Chinese civilization has often been remarked.
- Archaeological discoveries at the Ch'in capital have revealed water-conduits of thick stoneware. When the ancient Asian nomads surrounded their camps with a rampart of earth, it is not surprising that the agrarian culture of China erected walls around its earliest cities.
- Commerce was dependent upon means of transportation. Often, these were very imperfect. Rivers, especially the Yangtze and its major tributaries, fortunately afforded access to much of the country and were plied by different kinds of craft.
- The triumph of Ch'in was intimately bound up with technical advance. Although the First Emperor had supported large-scale schemes before his conquest of all the Warring States, they were a matter of urgent necessity after 221 BC.
- The Chinese did not engage extensively in mining. However, they utilized by simple processes the widely scattered deposits of iron. They began early to burn the coal with which parts of the country were so well supplied.
- Chinese astronomers have amassed long series of observations on things which were not studied elsewhere, for example novae and supernovae, so important in current cosmological speculation.
- A high provincial official, Tu Shih, introduced a water-powered metallurgical blowing-engine in AD 31. The continuous blast thus afforded was of inestimable value to the state-owned iron industry and may have led directly to the production of steel.
- A nautical invention of supreme interest was the stern-post rudder, whose prototype has been discovered in a pottery model of a ship lately recovered from a Former Han tomb.
- A second improvement concerned the equine harness, now transformed into the highly efficient collar harness. This further advance on the Warring States model increased effective traction enormously.

3.6 KEY WORDS

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- **Veterinary Science:** It deals with the prevention, control, diagnosis, and treatment of diseases affecting the health of domestic and wild animals and with the prevention of transmission of animal diseases to people.
- **Hydraulics:** It is the scientific study of water and other liquids. This study mainly focuses upon the behaviour of liquids under the influence of mechanical forces.
- **Geomancer:** A person who practices geomancy. Geomancy means divination by means of lines and figures or by geographic features.
- **Feudalism:** It is a social system that existed in Europe during the Middle Ages in which people worked and fought for nobles who gave them protection and the use of land in return.
- **Clepsydra:** It also called the water clock. It is an ancient device used for measuring time by the gradual flow of water.

3.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Write a short note on the significant developments achieved during the Gupta period in India.
2. Write short notes on the following:
   (a) Contribution of Aryabhatt
   (b) Contribution of Varahamihira
   (c) Contribution of Bhaskara I.
3. How was commerce dependent upon means of transportation during the Classical Age in China?
4. What were the major accomplishments of the Chinese astronomers in the field of astronomy?

Long-Answer Questions

1. 'General medicine, along with veterinary and Ayurvedic medicine, made enormous advancement during the Gupta period.' Discuss the statement.
2. Discuss the major developments in the fields of metallurgy, chemistry and physics during the Gupta period.

3. Explain the concept of town planning and building technology which developed and attained new heights during the Classical Age in China.
4. Describe the application of various metals by the Chinese.

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3.8 FURTHER READINGS

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BLOCK - II
BIRTH OF MODERN SCIENCE AND TECHNOLOGY IN EUROPE (15TH AND 16TH CENTURIES)

UNIT 4 SCIENTIFIC PROGRESS IN MEDIEVAL EUROPE

Structure

4.0 INTRODUCTION

In this unit, you will study about the Scientific Revolution and the birth of modern science. It is difficult to trace the period in which the Scientific Revolution took place. Some believe that it took place in the 16th and 17th centuries, while others are of the opinion that it began towards the end of the Renaissance Age.

Irrespective of the period of the Scientific Revolution, we cannot deny the fact that this revolution laid the foundation of modern science. If we look at historical accounts, we would find that the Greeks were the first to explain the laws of nature and the Universe. Aristotelian theories on these fields of science were held in high esteem until Nicolaus Copernicus, William Gilbert, Galileo Galilei and Isaac Newton dismantled his theories related to cosmology. In this unit, you will also learn about the contributions of three European scientists who played a major role in the Scientific Revolution, namely William Gilbert, Galileo Galilei and Isaac Newton.

4.1 OBJECTIVES

After going through this unit, you will be able to:

- Describe the scientific progrem in medieval Europe
- Explain the birth of modern science

- Discuss the major contribution of Roger Bacon and Kepler in the field of science and technology

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4.2 BIRTH OF MODERN SCIENCE

During the 15th and 17th centuries, new ideas and knowledge emerged in the field of astronomy, medicine, physics, biology and chemistry. The ideas born in this era changed the ancient and medieval view of nature and prepared the foundation of modern science. This is why the era is referred to as Scientific Revolution. The term Scientific Revolution was coined in 1939 by philosopher and historian Alexandre Koyré to describe this epoch. Some scholars, however, have objected to the use of the term Scientific Revolution to refer to scientific advancements in the 16th and 17th centuries. For example, James Hannam, a scholar of pre-modern and early modern history of science, said: "The term 'scientific revolution' is another one of those prejudicial historical labels that explain nothing. You could call any century from the twelfth to the twentieth a revolution in science". He also said that this term 'does nothing more than reinforce the error that before Copernicus nothing of any significance to science took place'.

Most of the accounts claim that the Scientific Revolution began in Europe towards the end of the Renaissance Age and continued through the late 18th century. J.D. Bernal, a Marxist historian and scientist, said: 'The renaissance enabled a scientific revolution which let scholars look at the world in a different light.'

In 1984, Joseph Ben-David said:

> Rapid accumulation of knowledge, which has characterized the development of science since the 17th century, had never occurred before that time. The new kind of scientific activity emerged only in few countries of Western Europe, and it was restricted to that small area for about two hundred years. (Since the 19th century, scientific knowledge has been assimilated by the rest of the world).

The word 'science' is derived from the Latin word *scientia,* which means knowledge. For Thomas Jefferson, 'science' meant 'disciplines of knowledge'. In 1800, he wrote that 'sciences' that interests him are '…surgery, medicine, natural philosophy (this probably means physics), agriculture, mathematics, astronomy, geography, politics, commerce, history, ethics, law, arts, fine arts'. Today, we do not categorize geography, politics, history, ethics, commerce, arts and fine arts under 'science'.

Until 1840s, science was called 'natural philosophy'. Isaac Newton's book on gravity and motion is titled *Principia Mathematica Philosophiae Naturalis* (*The Mathematical Principles of Natural Philosophy*). Newton called himself a 'philosopher'.

We can trace the birth of modern science in ancient Greece. There were a number of faults in the laws and theories given by Greeks but we cannot deny the fact that Greeks were the first ones to explain natural laws. The reasons behind

their faulty laws and theories can be attributed to the fact that there were no instruments like telescope and microscope during that time. Thus, they had to rely on their senses for observations.

Many Greeks, during that time, argued that relying on senses was a faulty way to unravel the mysteries of the Universe. However, others believed that this method might be faulty but it was worthwhile. Aristotle, a Greek, was one of the important personalities in the field of science. Aristotle's view of the Universe and laws of motion was based on some beliefs which are as follows:

1. **Theory of elements:** According to Democritus' atomic theory, all matter was composed of atoms which were indivisible and indestructible. Some Greeks observed that there were three states of matter namely solid, liquid and gas. Some Greeks related this observation with the theory of four elements: water, earth, air and fire. According to them earth was solid, water was liquid and air belonged to the third state of matter named gas.

   Aristotle also tried to find out the presence of elements in different objects around him. For instance, he said that wood has three elements namely earth, fire and air. He justified this observation by saying that wood has the element of fire because it burns; it contains the element of earth because it is solid and it has the element of air because its ash floats on water. These observations by Aristotle and other Greeks contributed greatly to the field of modern science.

2. **Perfect circular orbits of the stars and planets:** Aristotle believed that the stars and planets orbit the Earth in perfect circles. This belief led to another belief that all celestial bodies were made of a*ether*, a perfect element. *Aether* was light, almost weightless, thus, he believed that the stars and planets, made of *aether*, could orbit the Earth in perfect circles. He also believed that all dropped objects fall towards the centre of the Earth. These beliefs gave rise to the Geocentric theory, i.e., the Earth is the centre of the Universe.

   Aristotle believed that the shape of the Earth is round because the shadow of the Earth on the Moon during a lunar eclipse is round.

3. **Law of motions:** According to Aristotle, objects that are made of elements of water and earth sink or fall towards the centre of the Earth. On the other hand, objects that are made of elements of fire and air float or rise. Aristotle believed that all the four elements move towards their natural place and that this natural motion continues unless hindered. He also said that objects move against their natural motion only when they are forced in a different direction.

It was not easy for thinkers and philosophers to attack Aristotle's observations and theories because all the observations made by him were interrelated. Thus, attacking one part of the observation meant attacking the whole system of Aristotelian observations. Also, most of the theories by Aristotle were accepted by the Church as well. Thus, attacking Aristotelian observations meant attacking the Church.

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During the Renaissance period, scholars were trying to uncover those Greek authors who criticized Aristotle and contradicted his theories. These scholars believed that ancient knowledge was perfect. However, when they read the accounts of Greek authors, they realized that the authors were contradicting one another. This forced the scholars to find out which theories were correct.

During this search, they found out that none of these theories were correct. Thus, they indulged themselves in finding the correct theories. This gave rise to experimentation and freethinking which proved beneficial for the growth of modern science.

New observations gave rise to new explanations, which dismantled the observations made by Aristotle. Nicolaus Copernicus was the first person who started dismantling Aristotle's concept of cosmology.

His observations required new explanations which gave rise to the works of Galileo Galilei and William Gilbert. Later, Isaac Newton explained the phenomena of the Universe in a detailed manner. Contributions of Galileo, Gilbert and Newton have been discussed in the next unit.

Ideas that led to the scientific revolution

The Scientific Revolution was not marked by any single change. Some of the ideas that led to the Scientific Revolution are as follows:

- Earlier, many religions believed that the Earth was the centre of the Universe. This fact was also mentioned in religious scriptures. However, the astronomical model of helio-centrism said that the Earth revolves around the Sun. This model came in conflict with religious beliefs and led to the Scientific Revolution.
- According to Aristotle, matter was made up of four elements– water, earth, fire and air. However, the concept of atoms challenged Aristotle's theory and led to the Scientific Revolution.
- Aelius Galenus believed that venous and arterial systems were two separate systems. However, William Harvey proved that blood circulated from arteries to veins. It was a revolutionary discovery from the point of view of human physiology.
- According to Aristotle, heavy bodies, by their nature, moved straight down toward their natural places; light bodies, by their nature, moved straight up toward their natural place; and ethereal bodies, by their nature, moved in unchanging circular motions. These ideas of Aristotle were replaced by the idea that all bodies are heavy and move according to the same physical laws.
- Inertia replaced the medieval impetus theory, according to which unnatural motion (such as 'forced' or 'violent' rectilinear motion) is caused by continuous action of the original force imparted by a mover into that which is moved.

Check Your Progress

1. Who coined the term Scientific Revolution?
2. Mention any two ideas that led to the emergence of the Scientific Revolution.

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4.3 RENAISSANCE SCIENTISTS

Renaissance means rebirth or renewal. As a cultural movement, its origin goes back to 14th century, and by the 16th century it had spread through the whole of Europe. In the context of Europe it marked a historic phase— the transition of Europe from the medieval to the modern age. Europe in the past had been under the domination of the Greeks and later the Romans. With the decline of the Roman Empire, Europe fell into the 'Dark Ages'. This was an age when feudalism was the order of the day and the Catholic Church had an all pervading control on the society. False beliefs and blind faith perpetrated by the Church as well as a feudal set-up led to the complete fragmentation of the society.

Renaissance proved to be the vital connect between the medieval times and the modern age. As an intellectual and cultural revival, it altered the history of Europe. All spheres of everyday life from religion to politics, science and literature witnessed change.

There was stress on reason and observation during Renaissance. As science advanced and made new progress every day, people shunned the dogmatic beliefs that had hitherto restricted their lives. Reason was supreme and everything was to be governed by a rationale. The prominent scientists of this period were the following:

(i) **Roger Bacon** (AD 1214–1294), a medieval English philosopher, who discovered uses of gunpowder and magnifying lenses. He also anticipated an improvement in ships with them becoming oarless and carriage that need not be horse drawn. His contributions are discussed ahead separately in this unit.

(ii) **Copernicus** (AD 1473–1543), a Polish priest who faced much flak for suggesting that the Sun and not the Earth was the centre of the universe and that the Earth and other heavenly bodies revolved around it. His discovery was in contention to the belief held by the church. He also suggested that the Earth rotated about its axis. His contributions are discussed ahead separately in this unit.

(iii) **Galileo** (AD 1564–1642) apart from being the inventor of telescope and studying the movement of heavenly bodies also proved the Copernican theory correct through his experiments and mathematical calculations. His contributions in the field of science and technology have been discussed in detail in the next unit.

(iv) Johannes Kepler (AD 1571–1630) discovered that the Earth and the planets revolve around the Sun in an elliptical orbit and not in a circular one as earlier believed. His contributions have been discussed ahead separately in this unit.

(v) Newton, a British scientist, famous for his theory of gravitation and laws of motion. His contributions in the field of science and technology have been discussed in detail in the next unit.

(vi) Halley theorized about the appearance of comets at regular periods.

(vii) There was great progress in the field of medicine.

(viii) Vesalius, a physician, wrote *De Humani Corporis Fabricia*, a study of anatomy.

4.3.1 Roger Bacon

Roger Bacon's most noteworthy philosophical accomplishments were in the fields of mathematics, natural sciences and language studies. A conspicuous feature of his philosophical outlook was his emphasis on the utility and practicality of all scientific efforts. Bacon was convinced that mathematics and astronomy are not morally neutral activities, pursued for their own sake, but have a deep connection to the practical business of everyday life.

Bacon is especially known for his emphasis on experience and on experimental science (*scientia experimentalis*), including optics, also called perspective (*perspectiva* or *scientia de aspectibus*). Many of his reflections on the physical world were presented in the context of his extensive critique of university learning dating from the 1260s, which often times lent a rhetorical and pedagogical tenor. However, Bacon's contributions to this field were not restricted to polemics. Apart from the papal *opera* (*Opus Maius*, *Opus Minus*, and *Opus Tertium*), his most important works on mathematical and physical topics were the *De Multiplicatione Specierum* ('On the Multiplication of Species'; dated prior to the papal *opera*), the *Communia Naturalium*, and the *Communia Mathematica*, both dated after 1267.

Bacon modified the inherited division by adding new sciences to the traditional four (arithmetic, geometry, music and astronomy). He identified a list of seven 'special sciences,' among which he included perspective (optics), judicial astronomy (astrology), the science of weights, medicine, experimental science, alchemy, and agriculture. Bacon held that three of these sciences are especially important: judicial astronomy, alchemy and experimental science.

Following Aristotle, Bacon held that 'all humans by nature desire to know' and are naturally drawn towards the beauty of wisdom and carried away by their love for it. Bacon emphasized that to ensure success in learning, it is necessary to first inquire into the method best suited for it, as there are better and worse ways to proceed in the sciences. In his *Compendium Studii Philosophiae* (*CSP*), Bacon distinguished between three ways of acquiring knowledge—knowledge

through authority, reason and experience—and he made it clear that not all three ways are of equal value. Neither authority nor reason are sufficient for knowledge because reliance on authority alone yielded belief but not understanding, while reason alone could not distinguish between true sentences and sentences having only the appearance of knowledge (*CSP*, ch. i, 396f). According to Bacon, achieving knowledge requires three things: (1) to heed to the structure of the scientific material and to begin with what is first, easier, and more general then proceed to what is later, more difficult, and more particular, (2) to proceed using the clearest possible words without causing confusion, and (3) to reach a level of certainty that leaves behind all doubt. For this, Bacon considered it crucial to employ experience, and, in regard to the order of learning, to precede experience with mathematics.

4.3.2 Copernicus

Nicolaus Copernicus, known as the father of modern astronomy, was a Polish monk and astronomer. He developed the heliocentric theory of the solar system. It replaced the geocentric theory of the cosmos, which had been developed by the Hellenistic astronomer Ptolemy. Just before his death, Copernicus published *On the Revolutions of the Celestial Spheres* in 1543. This is actually considered as the starting point of contemporary astronomy and the emergence of the Scientific Revolution. The Scientific Revolution, thus, overshadowed the medieval view of the world and substituted it with our modern command over physics, nature, biology and humans.

A Renaissance astronomer, Nicolaus Copernicus (1473–1543) was a Renaissance astronomer and the first person to formulate a comprehensive heliocentric cosmology. Published in 1543, Copernicus' magnum opus *On the Revolutions of the Celestial Spheres*, is often regarded as the seminal work in modern astronomy that began the Scientific Revolution. His most famous work, the study of the heliocentric model, with the Sun at the centre of the universe, advocated that the observed motions of celestial objects can be explained without putting the Earth at the centre of the universe. His work stimulated further scientific investigations and went on to become a landmark in the history of science, which is often referred to as the, Copernican Revolution.

In 1512 Copernicus moved to Frombork, a small town on the Baltic Sea coast. There, in April 1512, he participated in the election of Fabian of Lossainen as Prince-Bishop of Warmia. By June 1512, Copernicus was allotted external curia— a house outside the defensive walls of the cathedral mount. In 1514 he purchased the north-western tower within the walls of the Frombork stronghold. Copernicus retained both the residencies until his death. It is believed that from 1513 to 1516, Copernicus carried out his astronomical observations from his external curia and from 1522–43, from an unidentified 'small tower'. During the later part, it is presumed that he used old instruments modelled on ancient ones such as triquetrum, quadrant and armillary sphere. At Frombork Copernicus conducted over half of his more than 60 registered astronomical observations.

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Having settled permanently at Frombork, where he would reside till the end of his life; with interruptions in 1516–19 and 1520–21, Copernicus found himself at the Warmia chapter's economic and administrative centre, which was also one of Warmia's two chief centres of politics. In the politically complex situation of Warmia, threatened externally by the Teutonic Order's aggressions and internally subject to strong separatist pressures, Copernicus, together with part of the chapter, represented a programme of strict cooperation with the Polish Crown and demonstrated that he was consciously a citizen of the Polish-Lithuanian Republic. Soon after the death of Uncle Bishop Watzenrode, he participated in the signing of the Second Treaty of Piotrków Trybunalski (7 December 1512), governing the appointment of the Bishop of Warmia, declaring, despite opposition from part of the chapter, for loyal cooperation with the Polish Crown.

Copernicus was appointed the *magister piostoriae* in order to administer economic enterprises, after having fulfilled the duties of a chancellor since 1511. Despite such professional responsibilities, Copernicus continued with his astronomical observations especially pertaining to the Sun and Mars. His studies led to the discovery of Earth's eccentricity and the movement of solar apogee. It is believed that some of his observations during this period had connections with the reform of a Julian calendar made at the request of the Bishop of Fossombrone.

Copernicus drafted the manuscript of *Locationes mansorum desertorum* (*Locations of Deserted Fiefs*), during 1516 to 1521 while residing at Olsztyn Castle as economic administrator of Warmia. When Olsztyn was besieged by the Teutonic Knights during the Polish–Teutonic War (1519–21), Copernicus directed the defence of Olsztyn and Warmia by Royal Polish forces. He also represented the Polish side in the ensuing peace negotiations.

Apart from continuing with his astronomical observations, Copernicus also worked at the Royal Prussian Diet and with Duke Albert. Copernicus participated in all major political and economical discussions of the country and he also served as the personal adviser to King Sigismund. Copernicus' administrative experiences resulted in a book titled *Monetae Cudendae Ratioi* (1526) where he formulated an early iteration of the theory now termed as Gresham's Law, named after Thomas Gresham. Copernicus' theory of money and monetary reforms were widely read across Poland and Prussia for stabilizing their currency.

The secretary to Pope Clement VII, Johann Widmanstetter, in 1533 explained the heliocentric system to the former who was immensely pleased with it. Bernard Wapowski in 1535 wrote a letter to a gentleman in Vienna urging him to publish an enclosed almanac written by Copernicus. It is believed that the almanac was Copernicus' tables of planetary positions. However, Wapowski passed away soon after and nothing came of his letter.

Copernicus took part in the election of the successor of the Prince-Bishop of Warmia, Mauritius Ferber, who died in 1537. Copernicus was also one of the candidates for the post but Johannes Dantiscus was the chosen one (20 September

1537). Although Copernicus maintained friendly ties with the new Prince-Bishop initially, their relations strained later. Copernicus was known to have successfully treated his family members and later the elderly bishops. He is known to have consulted the physician to Duke Albert as well as the Royal physician of Poland.

Duke Albert summoned Copernicus in 1541 to treat the former's counsellor George von Kunheim. Kunheim was completely cured within a month of Copernicus' treatment. Upon his return, Copernicus continued with his astronomical observations and calculations.

Despite so much popularity, there was a section of people who remained at bay from Copernicus and ridiculed the same often. For example, Wilhelm Gnapheus, a Dutch refugee settled in Elblag, authored a Latin comedy, *Morosophus* (The Foolish Sage), portraying Copernicus as a haughty individual who chose to isolate himself from society to waste time doing silly astronomical calculations.

However, in 1551, eight years after Copernicus had died, his *Prussian Tables* was published by astronomer Erasmus Reinhold. The publication was sponsored by Copernicus' former military adversary, the Protestant Duke Albert. The work was quickly adopted by other astronomers.

Throughout this period of his life, Copernicus continued making astronomical observations and calculations, but only as his other responsibilities permitted and never in a professional capacity.

Some of Copernicus' close friends turned Protestant, but Copernicus never showed a tendency in that direction. The first attacks on him came from Protestants. Wilhelm Gnapheus, a Dutch refugee settled in Elblag, wrote a comedy in Latin, *Morosophus* (*The Foolish Sage*), and staged it at the Latin school that he had established there. In the play, Copernicus was caricatured as a haughty, cold, aloof man who dabbled in astrology, considered himself inspired by God, and was rumoured to have written a large work that was mouldering in a chest.

Elsewhere Protestants were the first to react to news of Copernicus' theory. Melanchthon wrote:

Some people believe that it is excellent and correct to work out a thing as absurd as did that Sarmatian astronomer who moves the earth and stops the sun. Indeed, wise rulers should have curbed such light-mindedness.

Nevertheless, in 1551, eight years after Copernicus' death, astronomer Erasmus Reinhold published, under the sponsorship of Copernicus' former military adversary, the Protestant Duke Albert, the *Prussian Tables*, a set of astronomical tables based on Copernicus' work. Astronomers and astrologers quickly adopted it in place of its predecessors.

4.3.3 Kepler

Best known for his eponymous laws of planetary motion and astronomical treatise such as *Astronomia nova*, Johannes Kepler was a 17th century German

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mathematician, astronomer and an astrologer. Kepler's other major works include *Harmonices Mundi* and *Epitome of Copernican Astronomy*. These works laid the foundation for Isaac Newton's theory of universal gravitation. Kepler was a teacher of Mathematics at a seminary school in Austria, where he went on to become an associate of Prince Hans Ulrich von Eggenberg. Later, Kepler assisted astronomer Tycho Brahe and then he became the imperial mathematician to Emperor Rudolf II and his two successors Matthias and Ferdinand II. Brahe continued with his teaching profession. He taught at a school in the Austrian city of Linz, and simultaneously continued his studies in the field of optics. He also invented an improved version of the refracting telescope.

Kepler began to systematically observe a bright new evening star that made an appearance in October 1604 (SN 1604). In astrological terms, the end of 1603 implied the beginning of a fiery trigon, the beginning of the ca. 800-year cycle of conjunctions. In the past, such periods were associated by astrologers with the rise of Charlemagne (ca. 800 years earlier) and the birth of Jesus Christ (ca. 1600 years earlier). Therefore, expectations of significant events, especially pertaining to the emperor were high. In this context, Kepler described the two new stars in his astronomical work *De Stella Nova* where he explained the star's astronomical properties while taking a sceptical approach to the many astrological interpretations circulating then. He noted the evening star's fading luminosity, speculated about its origin, and used the lack of observed parallax to discuss that it was in the sphere of fixed stars; further undermining the doctrine of the immutability of the heavens (the idea accepted since Aristotle that the celestial spheres were perfect and unchanging). The birth of a new star implied the variability of the heavens. In an appendix, Kepler also argued about the recent work by the Polish historian Laurentius Suslyga; he calculated that, if Suslyga's observation is to be considered legitimate, that accepted timelines were four years behind, then the Star of Bethlehem—analogous to the present new star—would have coincided with the first great conjunction of the earlier 800-year cycle.

Johannes Kepler's ten year long research on the planet Mars, resulted in his astronomical magnum opus *Astronomia Nova* (*A New Astronomy*). The work began with the analysis of Mars' orbit based on Tycho's observation. It also explained the first two laws of planetary motion. Kepler calculated and recalculated various approximations of Mars' orbit using an equant (the mathematical tool that Copernicus had eliminated with his system), eventually creating a model that generally agreed with Tycho's observations within two arc minutes (the average measurement error). However, Kepler was not satisfied with the complex and still slightly inaccurate result; at certain points the model differed from the data by up to eight arc minutes. The wide array of traditional mathematical astronomy methods having failed him, Kepler set about trying to fit an ovoid orbit to the data.

In Kepler's religious views, the Sun was the source of all the forces in the solar system. In order to conduct this study, Kepler drew an analogy on William

Gilbert's theory of the magnetic soul of the Earth from *De Magnete* (1600) and on his own work on optics. According to Kepler, the motive power radiated by the Sun weakened the distance. Kepler created a formula based on measurements of the aphelion and perihelion of the Earth and Mars, where, a planet's rate of motion is inversely proportional to its distance from the Sun. By 1602, Kepler reformulated the theory in terms of geometry. His second law of planetary motion was that planets sweep out equal areas in equal times.

Kepler's next move was to calculate the entire orbit of Mars using the geometrical rate law. After 40 failed attempts, he finally hit upon the concept of an ellipse. After he found an elliptical orbit which fits the Mars data, his immediate inference was that all planets move in ellipses, with the Sun at the centre of the solar system. This observation later came to be known as Kepler's first law of planetary motion. By the end of 1605, Kepler had completed drafting the manuscript of *Astronomia Nova* which was published in 1609.

Upon completion of the *Astronomia Nova*, Kepler focussed his attention on Rudolphine Tables, a comprehensive set of ephemerides (specific predictions of planet and star positions) based on the tables. His other works dealt with chronology, the life of Jesus, not to mention astrology and especially criticizing dramatic predictions of catastrophe such as Helisaeus Roeslin. He made an unsuccessful attempt at collaborating with Giovanni Antonio Magini, an Italian astronomer. Roeslin and Kepler both engaged in a series of published attacks and counter attacks. Philip Feselius, in his work, dismissed Roeslin's astrology. In response, Kepler prepared Tertius Interveniens, which acted as a mediating element between the two scholars.

Galileo Galilei, in 1610, discovered four satellites of the planet Jupiter, using his new telescope. Upon the publication of his account as Sidereus Nuncius, Galileo sought Kepler's opinion in order to consolidate his observations. Kepler's response was prompt and enthusiastic, which he expressed in the form of a short publication titled *Dissertatio cum Nuncio Sidereo* (*Conversation with the Starry Messenger*). Galileo's observations were endorsed by Kepler, who offered a series of speculations based on Galileo's observations on astronomy and cosmology. Later, in 1610, Kepler published his own observations involving the telescope. The work was titled *Narratio de Jovis Satellitibus* that supported Galileo's observations. Unfortunately, Galileo's reactions to *Astronomia Nova* was never published.

Galileo's telescopic discoveries inspired Kepler to indulge in more astronomical investigations. For this, he borrowed a telescope from the Duke Ernest of Cologne. His observations were compiled in the form of a manuscript in 1610 that got published as *Dioptrice* in 1611. In it, Kepler set out the theoretical basis of double-convex converging lenses and double-concave diverging lenses—and how they are combined to produce a Galilean telescope—as well as the concepts of real vs. virtual images, upright vs. inverted images, and the effects of

focal length on magnification and reduction. He also described an improved telescope—now known as the astronomical or Keplerian telescope—in which two convex lenses can produce higher magnification than Galileo's combination of convex and concave lenses

Around 1611, Kepler circulated a manuscript of what would eventually be published (posthumously) as *Somnium* (*The Dream*). Part of the purpose of *Somnium* was to describe what practicing astronomy would be like from the perspective of another planet, to show the feasibility of a non-geocentric system. The manuscript, which disappeared after changing hands several times, described a fantastic trip to the moon; it was part allegory, part autobiography, and part treatise on interplanetary travel (and is sometimes described as the first work of science fiction). Years later, a distorted version of the story may have instigated the witchcraft trial against his mother, as the mother of the narrator consults a demon to learn the means of space travel. Following her eventual acquittal, Kepler composed 223 footnotes to the story—several times longer than the actual text—which explained the allegorical aspects as well as the considerable scientific content (particularly regarding lunar geography) hidden within the text.

Work in mathematics and physics

A pamphlet titled *Strena Seu de Nive Sexangula* (*A New Year's Gift of Hexagonal Snow*) was composed by Kepler in honour of his friend and patron Baron Wackher von Wackhenfels. The treatise focussed on describing the hexagonal symmetry of snowflakes. It then went on to discuss a hypothetical atomistic physical basis for the symmetry, which later came to be known as the Kepler conjecture. Till date, Kepler is remembered as one of the pioneers of the mathematical applications of infinitesimals.

Clearly, despite some drawbacks, the Industrial Revolution actually transformed the manner of functioning of the entire world economy. Every section of the society and industry was affected in some way or the other. Change was seen in every sphere of life. The fields of science, technology and astronomy saw many inventions and discoveries taking place. Naturally, there was improvement in people's lives. The tools and machines used by people in the modern age owe a lot to the revolution that took place in the past.

Kepler propounded three laws of planetary motion:

(i) **First Law of Planetary Motion:** Planets move in ellipses with the Sun at one focus.

(ii) **Second Law of Planetary Motion:** The radius vector describes equal areas in equal times.

(iii) **Third Law of Planetary Motion:** The squares of the periodic times are to each other as the cubes of the mean distances.

Check Your Progress

3. State two significant features of the Renaissance.
4. Name the three sciences which were considered important by Roger Bacon.
5. Who is known as the father of modern astronomy?
6. What was the second law of the planetary motion discovered by Kepler?
7. What was the significant feature of the Keplerian telescope?

4.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The term Scientific Revolution was coined in 1939 by philosopher and historian Alexandre Koyré to describe this epoch.
2. Some of the ideas that led to the Scientific Revolution are as follows:
   - According to Aristotle, matter was made up of four elements– water, earth, fire and air. However, the concept of atoms challenged Aristotle's theory and led to the Scientific Revolution.
   - Aelius Galenus believed that venous and arterial systems were two separate systems. However, William Harvey proved that blood circulated from arteries to veins. It was a revolutionary discovery from the point of view of human physiology.
3. Two significant features of the Renaissance are the following:
   (i) There was stress on reason and observation during Renaissance.
   (ii) Renaissance proved to be the vital connect between the medieval times and the modern age. As an intellectual and cultural revival, it altered the history of Europe. All spheres of everyday life from religion to politics, science and literature witnessed change.
4. Bacon held that three of these sciences are especially important: judicial astronomy, alchemy and experimental science.
5. Nicolaus Copernicus is known as the father of modern astronomy.
6. Kepler's second law of planetary motion was that planets sweep out equal areas in equal times.
7. The significant feature of Keplerian telescope was that two convex lenses could produce higher magnification than Galileo's combination of convex and concave lenses.

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4.5 SUMMARY

- During the 15th and 17th centuries, new ideas and knowledge emerged in the field of astronomy, medicine, physics, biology and chemistry.
- Most of the accounts claim that the Scientific Revolution began in Europe towards the end of the Renaissance Age and continued through the late 18th century.
- Until 1840s, science was called 'natural philosophy'. Isaac Newton's book on gravity and motion is titled *Principia Mathematica Philosophiae Naturalis* (*The Mathematical Principles of Natural Philosophy*). Newton called himself a 'philosopher'.
- According to Aristotle, objects that are made of elements of water and earth sink or fall towards the centre of the Earth.
- During the Renaissance period, scholars were trying to uncover those Greek authors who criticized Aristotle and contradicted his theories. These scholars believed that ancient knowledge was perfect.
- Nicolaus Copernicus was the first person who started dismantling Aristotle's concept of cosmology.
- Renaissance means rebirth or renewal. As a cultural movement, its origin goes back to 14th century, and by the 16th century it had spread through the whole of Europe.
- Renaissance proved to be the vital connect between the medieval times and the modern age. As an intellectual and cultural revival, it altered the history of Europe. All spheres of everyday life from religion to politics, science and literature witnessed change.
- Roger Bacon's most noteworthy philosophical accomplishments were in the fields of mathematics, natural sciences and language studies.
- Bacon modified the inherited division by adding new sciences to the traditional four (arithmetic, geometry, music and astronomy). He identified a list of seven 'special sciences,' among which he included perspective (optics), judicial astronomy (astrology), the science of weights, medicine, experimental science, alchemy, and agriculture.
- Nicolaus Copernicus, known as the father of modern astronomy, was a Polish monk and astronomer. He developed the heliocentric theory of the solar system.
- In 1512 Copernicus moved to Frombork, a small town on the Baltic Sea coast. There, in April 1512, he participated in the election of Fabian of Lossainen as Prince-Bishop of Warmia.

- Copernicus was appointed the *magister piostoriae* in order to administer economic enterprises, after having fulfilled the duties of a chancellor since 1511.
- Copernicus took part in the election of the successor of the Prince-Bishop of Warmia, Mauritius Ferber, who died in 1537.
- Best known for his eponymous laws of planetary motion and astronomical treatise such as *Astronomia nova*, Johannes Kepler was a 17th century German mathematician, astronomer and an astrologer.
- Kepler began to systematically observe a bright new evening star that made an appearance in October 1604 (SN 1604). In astrological terms, the end of 1603 implied the beginning of a fiery trigon, the beginning of the ca. 800-year cycle of conjunctions.
- Johannes Kepler's ten year long research on the planet Mars, resulted in his astronomical magnum opus *Astronomia Nova* (*A New Astronomy*).
- Upon completion of the *Astronomia Nova*, Kepler focussed his attention on *Rudolphine Tables*, a comprehensive set of ephemerides (specific predictions of planet and star positions) based on the tables.
- Galileo Galilei, in 1610, discovered four satellites of the planet Jupiter, using his new telescope. Upon the publication of his account as Sidereus Nuncius, Galileo sought Kepler's opinion in order to consolidate his observations.
- A pamphlet titled *Strena Seu de Nive Sexangula* (*A New Year's Gift of Hexagonal Snow*) was composed by Kepler in honour of his friend and patron Baron Wackher von Wackhenfels.

4.6 KEY WORDS

- **Human Physiology:** It is the study of the body and its functions in each of the different systems in any living body.
- **Inertia:** It is the resistance of any physical object to any change in its velocity.
- **Renaissance**: It means rebirth or renewal. As a cultural movement, its origin goes back to 14th century, and by the 16th century it had spread through the whole of Europe.
- **Polemics:** It is an aggressive attack on or refutation of the opinions or principles of another person.
- **Apogee:** It is the point in the orbit of a heavenly body, especially the moon, or of a man-made satellite at which it is farthest from the earth.

4.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

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Short-Answer Questions

1. Mention the significant features of the Scientific Revolution.
2. What were the three ways of acquiring knowledge as defined by Roger Bacon?
3. What is known as the Copernican Revolution?

Long-Answer Questions

1. 'Renaissance proved to be the vital connect between the medieval times and the modern age.' Elucidate the statement.
2. Discuss the major contribution of Nicolaus Copernicus in the field of astronomy.
3. Examine the major findings of Kepler's as discussed in his magnum opus *Astronomia Nova*.

4.8 FURTHER READINGS

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UNIT 5 GALILEO, GUTENBERG, NEWTON AND HARVEY

Structure

5.0 INTRODUCTION

Galileo, Newton, Gutenberg and Harvey immensely contributed to the Scientific Revolution with their major inventions and achievements. Galileo adopted an innovative and experiment based approach which made one of the chief figures of the Scientific Revolution. Likewise, Issac Newton acquired recognition and fame through his invention of the telescope in 1668. William Harvey was another notable figure of this period who conducted several experiments and confirmed the flow of blood in the entire human body. In this unit, you will study about the significant contribution of Galileo, Newton, Gutenberg and Harvey in the field of science and technology.

5.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the establishment of scientific academies
- Explain the contribution of Galileo and Gutenberg
- Describe the works of Newton and William Harvey

5.2 FOUNDATION OF SCIENTIFIC ACADEMIES

The revival of interest in scientific experiment begins in the Renaissance and spread rapidly during the 17th century. This development is reflected in the establishment of scientific academies.

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The first is probably the Academia Secretorum Naturae (Academy of the Secrets of Nature), founded in Naples in 1560 by Giambattistadella Porta. His interest was in magic and science. Both subjects alarm those defending the orthodoxies of the Catholic Reformation, and Della Porta's academy is investigated by the Inquisition in 1580. Galileo, another scientist falling foul of the Inquisitors, was a member of a famous Roman academy of the early 17th century, the Accademiadei Lincei.

In 1657 Florence had an Accademia del Cimento, founded by the Medici family. But the two most influential scientific academies of the 17th century evolve slowly from informal beginnings. In the 1640s, gentlemen with scientific interests in both England and France made it a habit of meeting to share their experimental discoveries.An English group met at Wadham College in Oxford from 1648 to 1659, and then in London's Gresham College. Formed into an academy in 1660, it was given a charter by Charles II in 1662 and became the Royal Society. The equivalent French group was invited by Colbert in 1666 to hold meetings in the royal library, and in 1699 the Académie des Sciences with premises in the Louvre got established.

Among the most important planned activities of Académie des Sciences that did become a reality was astronomical observation because observation of the sky was the basis for the Academy's vast project to advance the understanding of terrestrial longitude as a way to improve French mapmaking.

The inauguration of the Royal Society in London in 1660 and its receipt of a royal charter in 1662 played a fundamental role in the promotion of an experimental philosophy and the creation of a new kind of scientific community in England. The subsequent foundation of the Paris Academy of Sciences in 1666, as a royal institution offering enticing stipends and the promise of research facilities to attract Europe's best scientific minds to France, provided an alternative model to its London counterpart. Under the patronage of the French minister Colbert, the Paris Academy of Sciences made the idea of a scientific society more overtly a political project, making state sponsorship of science an integral part of the emerging image of France as a nation that rewarded talent, cultivated expertise, and considered the advancement and control of knowledge to be a measure of national prosperity.

In subsequent decades, the transformation of the Academy for the Curious of Nature (1652-93), from a physicians' club which moved from one German town to another into an academy with an imperial charter in 1671 and Leibniz's realization of the Berlin Academy of Sciences in 1700 under Frederick I reflected the expanding role of academies in the promotion of scientific research and communication. Numerous provincial cities supported private and occasionally state-sponsored initiatives such as the Collegium Curiosorum (1710-11) in Uppsala,

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which became the Royal Society of Sciences in 1728. As far away as St. Petersburg, the idea of an academy that could play a fundamental role in the modernizing projects of Peter the Great was also in the works though it would not receive its official charter until 1724.

Drawing inspiration from the writings of such figures as Bacon, Descartes, Galileo and Leibniz, early modern scientific societies advocated the reformation and progress of knowledge as a project of great benefit to society. Harnessing the best features of the republic of letters, they sought to make scholarly networks deliberately productive associations based on membership rather than voluntary association. Academies brought scholars together, concentrating talent, pooling resources, and promoting new forms of collaboration that often culminated in novel publications such as the learned journal or academy-sponsored books. They institutionalized practices that had already been under development in the preceding century while also being self-conscious about their goal of supporting further innovations that would contribute to the modernization of knowledge. The scientific academy became simultaneously a repository of information, instruments and specimen—a space in which to conduct and present one's research, a deliberative body whose collective expertise might potentially resolve intellectual differences through commonly agreed upon procedures, and an organ of publicity through its correspondence networks and publications. Fundamentally, the scientific academy represented the new prestige of natural knowledge and mathematics as a matter of public interest. These were the ingredients that made the learned society the institutional embodiment of the promise of the new science, and they were ideals forged in the republic of letters.

The proliferation of academies by the 18th century led the most famous academician of this age, the Paris Academy's perpetual secretary Bernard le Bovier de Fontenelle, to declare it an 'age of academies.' Academies were not only engines of knowledge in the late 17th and eighteenth centuries—communities of scholars collecting, assessing, and creating knowledge, just as Bacon had prophesied—but they were also a subject of great discussion within the republic of letters. Creating an academy added something tangible to a rapidly evolving institutional landscape whose participants sought to change not only what kind of knowledge mattered but how knowledge itself was produced. The growing number of learned academies by the 18th century made the project of reforming knowledge more than just an informal conversation among scholars. It was increasingly supported by an infrastructure which presented the learned academy as the culmination of a new understanding of the value of knowledge.

What, then, was Italy's contribution to these exciting new developments? In the 17th century, Italy created more scientific academies than established in any other part of Europe—indeed more academies of any kind—and yet virtually

none of them remained active by 1700. All the scientific academies founded in the early to mid-17th century—most notably the Accademiadei Lincei (1603-30) and Accademia Fisico-Matematica (1677-98) in Rome, the Accademia del Cimento (1657-67) in Florence, and the Accademiadegli Investiganti (1663-70) in Naples, and the Accademiadella Traccia (1666- ca.1678) in Bologna—had vanished.

With the noteworthy exceptions of the Accademiadegli Inquieti (1690-1714) in Bologna, the Accademiadegli Argonauti (1684-1718) in Venice, and the Accademiadei Fisiocritici in Siena, few vestiges of Italy's glorious tradition of creating scientific academies survived into the next century. This was of course old news by the time Dereham summed up the state of Italian science in the 1720s and the Royal Society had been well-informed by travellers and correspondents about the activities of many of these fleeting initiatives. The question in 1722 was not what the Italian academies looked like in the past but what future developments might bring. Would any of the Italian states and their leading citizens ever find the means of creating a more enduring scientific institution?

5.2.1 Contributions of Galileo Galilei

Galileo Galilei played an important role in the Scientific Revolution. He was an Italian mathematician, philosopher, astronomer and physicist. He supported the theories of Copernicus. He is called the 'father of modern science' and the 'father of modern observational astronomy'.

Eye glasses were used in the 13th century. In 1609, a discovery was made in the Netherlands which said that distant objects seem close if a person sees them by putting two lenses together. When Galileo heard about this discovery, he invented an astronomical telescope. With the help of this telescope, he made a number of observations. Some of the observations made by him are as follows:

i. He discovered the four largest satellites of Jupiter. These satellites are named 'Galilean moons' to honour his contribution. A number of scientists at that time believed that there could only be one centre of motion in the Universe. With the help of a telescope, Galileo proved that there were three centres of motion- the Earth, the Sun and Jupiter.

ii. Galileo confirmed the phases of Venus with the help of telescope. Copernicus said that Venus had phases but scientists did not believe him. However, Galileo proved that Copernicus's observation related to the phases of Venus was correct.

iii. He also observed that there were mountains and valleys on the Moon. Before this discovery, people believed that the heaven, which included the Moon, was unlike the Earth. This discovery shook religious beliefs of people to a large extent.

iv. He also proved that we cannot see all the stars with our naked eyes and the Milky Way had a number of stars.

Some of his critics at that time said that telescope was creating illusions. They based this criticism on the fact that when they looked at the stars with the help of telescope, some of the stars looked double. With the help of this argument, they tried to prove that telescope was not reliable. However, some years later, it was proved that many stars are double.

One of the greatest achievements of Galileo is that he used mathematics to explain motion. Aristotle did not use mathematics in his theories. Aristotle said that heavier objects fall faster. When Galileo tried to check this theory, he found that this theory was wrong. He found out that everything falls at the same rate and also found out the way to calculate that rate. For this, he differentiated between velocity and acceleration. He also discovered that we cannot feel velocity but we can feel acceleration.

He also made efforts to prove that Copernican astronomy was correct. He was supported by his friend Johannes Kepler, a great astronomer. The Catholic Church was against Galileo as some of his discoveries challenged views of the Church. However, soon Maffeo Barberini, his friend, became Pope Urban VIII. He allowed Galileo to write about Ptolemaic and Copernican systems.

Galileo wrote *A Dialogue on the Two Principal Systems of the World* in 1632. In the book, he made the representative of the Ptolemaic system look foolish. The Pope thought that Galileo created his caricature in this book. Thus, Galileo was 'shown the instruments of torture'. As a punishment, he was kept under house arrest for the rest of his life.

Galileo's contributions to technology

Galileo contributed immensely to the field of technology. He improved geometric and military compass that could be used by surveyors and gunners. He also found out the way to compute the charge of gunpowder for cannonballs. This geometric instrument enabled people to construct regular polygons and calculate the area of polygons. In addition, people could calculate the area of circular sector with the help of this compass. Marc'Antonio Mazzoleni, an instrument maker, made more than 100 compasses under Galileo's guidance. Galileo wrote a manual to explain the use of these compasses.

In 1609, Galileo used a refracting telescope to observe stars, planets and moons. The instrument invented by Galileo was named 'telescope' by Giovanni Demisiani, a Greek mathematician. The word 'telescope' is derived from two Greek words *tele* and *skopein*. *Tele* means 'far' and *skopein* means 'to look' or 'see'. In 1610, Galileo used his telescope to see the parts of insects in a magnified manner. In 1624, he was able to make a compound microscope.

Galileo's writings

In 1586, Galileo wrote a book titled *La Billancetta* (*The Little Balance*). This book described the use of a balance which could weigh objects in air and water accurately. In 1606, he wrote a manual titled *Le Operazioni del Compasso Geometricoet Militare* which described the use of geometrical and military compass.

He wrote *Pisan De Motu* (*On Motion*) and *Paduan Le Meccaniche* (*Mechanics*) in 1590 and 1600 respectively. In 1610, he wrote *The Starry Messenger* (*Sidereus Nuncius*). This scientific treatise includes accounts of his discoveries and observations such as presence of mountains on the Moon, appearance of the Milky Way and discovery of the Galilean moons. In 1613, he wrote *The Letters on Sunspots* in which he described sunspots in detail. This book also includes his observation related to the phases of Venus and 'appendages' of Saturn.

Some of the other books written by Galileo are as follows:

- *Discourse on Floating Bodies* (1612)
- *Letter to the Grand Duchess Christina* (written in 1615 and published in 1636)
- *Discourse on the tides* (1616)
- *The Assayer—Il Saggiatore* (1623)
- *Dialogue Concerning the Two Chief World Systems* (1632)
- *Discourses and Mathematical Demonstrations Relating to Two New Sciences* (1638)

5.2.2 Contribution of Johannes Gutenberg

There are some inventions that have changed the course of human history and the printing press is one of them. As the name suggests, this machine allowed for the mass production of printed matter like newspapers and books. Its function sounds unremarkable today, but when the printing press was refined by Johannes Gutenberg in the 15th century, it was nothing short of revolutionary.

The most common iteration of the printing press is the Gutenberg press—but it was not the first. It is not known as to who invented the initial printing press, but the oldest known printed text came from China, which is called *The Diamond Sutra*, a Buddhist scroll that was published around 868 CE.

Johannes Gutenberg was born in Mainz, Germany around the year 1398. He was the son of a Goldsmith. Johannes introduced the concept of movable type and the printing press to Europe. While this may not sound like a big deal at first,

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the printing press is often considered as the most important invention in modern times. Think about how important information is today. Without books and computers you would not be able to learn, to pass on information, or to share scientific discoveries. Prior to Gutenberg introducing the printing press, making a book was a laborious process in Europe. It was not that hard to write a letter to one person by hand, but to create thousands of books for many people to read was nearly impossible. Without the printing press we would not have had the Scientific Revolution or the Renaissance.

Gutenberg took some existing technologies and some of his own inventions to come up with the printing press in the year 1450. One key idea he came up with was movable type. Rather than use wooden blocks to press ink onto paper, Gutenberg used movable metal pieces to quickly create pages. Gutenberg introduced innovations all the way through the printing process enabling pages to be printed much more rapidly. His presses could print 1000's of pages per day versus only 40-50 pages with the old method. This was a dramatic improvement and allowed books to be acquired by the middle class for the first time in the history of Europe. Knowledge and education spread throughout the continent like never before. The invention of the printing press spread rapidly throughout Europe and soon thousands of books were being printed on printing presses.

It is thought that the first printed item from the press was a German poem. Other prints included Latin Grammars and indulgences for the Catholic Church. Gutenberg's real fame came from producing the Gutenberg Bible. It was the first time a Bible was produced on a mass scale and available for anyone outside the church. Bibles were rare and could take up to a year for a priest to transcribe. Gutenberg printed around 200 Bibles in a relatively short time.

The Gutenberg printing press had several innovations on Chen’s machine. The most notable is that the formerly wooden blocks were now made of metal. Additionally, each letter was its own block, and those blocks were produced on a large scale. To replicate the type in such quantities, brass moulds were created and then had molten lead poured in them. They fitted together in a way that the lines of the letters were consistent and appeared uniform on paper.

There were other aspects of the Gutenberg press that made it one of the world’s most successful innovations. Gutenberg developed his own ink that stuck to metal, and he repurposed wine and olive presses—something used to press grapes for wine and olives for oil—into a means of flattening paper.

5.2.3 Contribution of Isaac Newton

Sir Isaac Newton was an English astronomer, physicist, mathematician, natural alchemist, philosopher and theologian. According to Daniel S. Burt, Newton was ‘the greatest and most influential scientist who ever lived’. *Philosophiæ Naturalis*

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Principia Mathematica (*Mathematical Principles of Natural Philosophy*) was Newton's monograph which was published in 1687.

In this monograph, Newton explained the three laws of motion and universal gravitation. He explained Kepler's laws of planetary motion and his own theory of gravitation. The word 'gravity' is derived from a Latin word *gravitas* which means weight.

Newton is popular for his theory of colour, law of cooling, and his observation on speed of sound. He contributed a lot to the field of mathematics. He developed differential and integral calculus with the help of Gottfried Leibniz. He explained binomial theorem and developed a method for approximating the roots of a function.

In 1679, Newton started working on (celestial) mechanics once again. A brief exchange of letters with Robert Hooke encouraged him to restart this work. After the appearance of a comet in the winter of 1680–1681, he started taking interest in astronomical matters.

The Principia written by him is considered to be one of the most important books in science. This book was published on 5 July 1687. After the publication of this book, he became very popular. Edmond Halley, an English astronomer, helped Newton financially in the publication of this book. This book contains the following essential facts:

- A calculus-like method of geometrical analysis by 'first and last ratios'.
- The first analytical determination (based on Boyle's law) of the speed of sound in air.
- The ellipticity of the spheroidal figure of the Earth.
- The precession of the equinoxes as a result of the Moon's gravitational attraction on the Earth's ellipticity.
- The gravitational study of the irregularities in the motion of the moon.
- The determination of the orbits of comets.

Newton's laws of motion formed the basis for classical mechanics. These laws are as follows:

i. **First law**: The velocity of a body remains constant unless the body is acted upon by an external force.

ii. **Second law**: The acceleration 'a' of a body is parallel and directly proportional to the net force 'F' and inversely proportional to the mass m, i.e., $F = ma$.

iii. **Third law**: The mutual forces of action and reaction between two bodies are equal, opposite and collinear.

The first two laws oppose Aristotle's belief that force is required to maintain motion. Newton's physics is universal in nature. For instance, the second law of motion is applicable to the planets as well as a falling stone.

The SI unit of force is named 'newton'. This unit was named 'newton' in order to honour Newton's contribution to the field of science.

5.2.4 Contribution of William Gilbert

William Gilbert was an English physicist, physician and natural philosopher. He rejected the philosophy of Aristotle and supported the observations of Nicolaus Copernicus. He is known as the 'father of electrical engineering or electricity and magnetism'.

During his lifetime, sailors used to use magnetic compass for navigation. However, there were doubts regarding the working of magnetic compass. Christopher Columbus believed that the Pole Star attracted magnetic compass' needle. Some people even thought that needle worked due to the magnetism quality of mountains in the Arctic.

William Gilbert was curious to know how magnetic compass worked. Thus, he conducted experiments for 17 years. His book *De Magnete*, *Magneticisque Corporibus, et de Magno Magnete Tellure* (On the Magnet and Magnetic Bodies, and on the Great Magnet the Earth), published in 1600, was a huge success in Europe. In this book, he described the experiments which he conducted for 17 years. He concluded that the Earth was magnetic. He also said that the centre of the Earth was made of iron.

In this book, he wrote his observations related to static electricity. The word 'electricity' is derived from a Latin word *çlectricus*, which means 'amber-like'. William Gilbert coined this term when he made a careful study on electricity. The term was named so because during that time electrical effects were produced by rubbing amber.

William Gilbert invented electroscope, the first electrical measuring instrument. Gilbert believed that magnetism and electricity were two different things. However, the reasons he gave for justifying this statement were proved wrong by many scientists. In 1590s, he tried to map the surface markings of the Moon. He was the first scientist who attempted to do this without using the telescope.

5.2.5 Contribution of William Harvey

Harvey was born at Folkestone, Kent, England on 1 April 1578. He received the degree of Medical Doctor from the University of Padua, Italy in 1602. After his return to England, he became Fellow of the College of Physicians, physician to St. Bartholomew's Hospital and Lumleian lecturer at the College of Physicians. In

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1618, Harvey was appointed physician extraordinary to James I, and he remained in close professional relations to the royal family. He died on 3 June 1657 at the age of 79 years. His last contribution was a book on the growth and development of the young animals entitled 'De Generatione Animalium', published in 1651.

Harvey focused much of his research on the mechanics of blood flow in the human body. Most physicians of the time felt that the lungs were responsible for moving the blood throughout the body. Harvey's famous 'Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus', commonly referred to as *de Motu Cordis* was published in Latin at Frankfurt in 1628, when Harvey was 50 years old. The first English translation did not appear until two decades later.

Harvey, having observed the motion of the heart in living animals, he was able to see that systole was the active phase of the heart's movement, pumping out the blood by its muscular contraction. Having perceived that the quantity of blood issuing from the heart in any given time was too much to be absorbed by the tissues, he was able to show that the valves in the veins permit the blood to flow only in the direction of the heart and to prove that the blood circulated around the body and returned to the heart. Fabricius, his teacher in Padua, had discovered the valves in the veins.

In Chapter 13 of *de Motu Cordis*, Harvey summarized the substance of his findings:

> It has been shown by reason and experiment that blood by the beat of the ventricles flows through the lungs and heart and is pumped to the whole body. There it passes through pores in the flesh into the veins through which it returns from the periphery everywhere to the centre, from the smaller veins into the larger ones, finally coming to the vena cava and right atrium. This occurs in such an amount, with such an outflow through the arteries and such a reflux through the veins, that it cannot be supplied by the food consumed. It is also much more than is needed for nutrition. It must therefore be concluded that the blood in the animal body moves around in a circle continuously and that the action or function of the heart is to accomplish this by pumping. This is only reason for the motion and beat of the heart.

Check Your Progress

1. In which year was the Royal Society established in London?
2. When was *A Dialogue on the Two Principal Systems of the World* published?
3. Mention the significant works of Galileo.
4. What was the source of the oldest known printed text?
5. State the Newton's three laws of motion.
6. When and where was William Harvey born?

5.3 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The Royal Society was established in London in the year 1660.
2. *A Dialogue on the Two Principal Systems of the World* was published in 1632.
3. The significant works of Galileo are the following:
   - *Discourse on Floating Bodies* (1612)
   - *Letter to the Grand Duchess Christina* (written in 1615 and published in 1636)
   - *Discourse on the tides* (1616)
   - *The Assayer—Il Saggiatore* (1623)
   - *Dialogue Concerning the Two Chief World Systems* (1632)
   - *Discourses and Mathematical Demonstrations Relating to Two New Sciences* (1638)
4. The oldest known printed text came from China. Called *The Diamond Sutra*, it is a Buddhist scroll that was published around 868 CE.
5. Newton's three laws of motion are as follows:
   (i) First law: The velocity of a body remains constant unless the body is acted upon by an external force.
   (ii) Second law: The acceleration 'a' of a body is parallel and directly proportional to the net force 'F' and inversely proportional to the mass m, i.e., $F = ma$.
   (iii) Third law: The mutual forces of action and reaction between two bodies are equal, opposite and collinear.
6. Harvey was born at Folkestone, Kent, England on 1 April 1578.

5.4 SUMMARY

- The revival of interest in scientific experiment begins in the Renaissance and spread rapidly during the 17th century. This development is reflected in the establishment of scientific academies.
- An English group met at Wadham College in Oxford from 1648 to 1659, and then in London's Gresham College.
- Among the most important planned activities of *Académie des Sciences* that did become a reality was astronomical observation because observation

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of the sky was the basis for the Academy's vast project to advance the understanding of terrestrial longitude as a way to improve French mapmaking.

- Academies brought scholars together, concentrating talent, pooling resources, and promoting new forms of collaboration that often culminated in novel publications such as the learned journal or academy-sponsored books.
- The proliferation of academies by the 18th century led the most famous academician of this age, the Paris Academy's perpetual secretary Bernard le Bovier de Fontenelle, to declare it an 'age of academies.'
- Galileo Galilei played an important role in the Scientific Revolution. He was an Italian mathematician, philosopher, astronomer and physicist. He supported the theories of Copernicus. He is called the 'father of modern science' and the 'father of modern observational astronomy'.
- One of the greatest achievements of Galileo is that he used mathematics to explain motion. Aristotle did not use mathematics in his theories. Aristotle said that heavier objects fall faster.
- Galileo wrote *A Dialogue on the Two Principal Systems of the World* in 1632. In the book, he made the representative of the Ptolemaic system look foolish.
- The most common iteration of the printing press is the Gutenberg press—but it was not the first. It is not known as to who invented the initial printing press, but the oldest known printed text came from China. Called *The Diamond Sutra*, it is a Buddhist scroll that was published around 868 CE.
- Gutenberg took some existing technologies and some of his own inventions to come up with the printing press in the year 1450.
- The Gutenberg printing press had several innovations on Chen's machine. The most notable is that the formerly wooden blocks were now made of metal.
- In this monograph, Newton explained the three laws of motion and universal gravitation. He explained Kepler's laws of planetary motion and his own theory of gravitation. The word 'gravity' is derived from a Latin word *gravitas* which means weight.
- In 1679, Newton started working on (celestial) mechanics once again. A brief exchange of letters with Robert Hooke encouraged him to restart this work. After the appearance of a comet in the winter of 1680–1681, he started taking interest in astronomical matters.
- William Gilbert was an English physicist, physician and natural philosopher. He rejected the philosophy of Aristotle and supported the observations of

Nicolaus Copernicus. He is known as the 'father of electrical engineering or electricity and magnetism'.

- Harvey was born at Folkestone, Kent, England on 1 April 1578. He received the degree of Medical Doctor from the University of Padua, Italy in 1602.
- Harvey's famous 'ExercitatioAnatomica de Motu Cordis et Sanguinis in Animalibus', commonly referred to as *de Motu Cordis* was published in Latin at Frankfurt in 1628, when Harvey was 50 years old. The first English translation did not appear until two decades later.

5.5 KEY WORDS

- **Vestige:** It is the a mark, trace, or visible evidence of something that is no longer present or in existence
- **Transcribe:** It implies to put thoughts, speech or data into written or printed format.
- **Monograph:** It is is a long, detailed scholarly piece of writing on a specific subject.

5.6 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What were the significant changes which happened with the foundation of the scientific academies?
2. Write a short note on the contribution of Galileo Galilei.
3. Who is known as the 'father of electrical engineering or electricity and magnetism'?

Long-Answer Questions

1. Discuss the establishment of scientific academies during the 17th and 18th centuries.
2. Examine the significance of Gutenberg's invention of the printing press.
3. Explain the significant contribution of Issac Newton.
4. Analyze the contribution of William Harvey with special reference to the human anatomy.

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5.7 FURTHER READINGS

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UNIT 6 SCIENCE AND TECHNOLOGY IN 18TH AND 19TH CENTURIES

Structure

6.0 INTRODUCTION

The 18th and 19th centuries (period of Industrial Revolution in Europe and the US) witnessed several changes in the field of science and technology, beginning with the textile industry, iron ore and then spreading to other sectors. Europe witnessed some of the best scientific inventions of the 19th century. Many new branches of science, such as anthropology, archaeology and cell biology came into existence. The science of Geology matured, especially in the area of fossils and the movement of the Earth. The occupation of 'scientist' became a paid position. Research labs became attached to universities and scientists took up the profession of teaching at universities as well. Universities and sometimes the government granted funds, thereby enabling the general public to conduct research and experiments in science and related fields. By 1822, national scientific congresses were held in Germany, which was the first step to the organization of international congresses by the middle of the century.

6.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the prominent developments which took place in the field of science and technology in the 18th and 19th centuries
- Examine the contribution of Darwin, Faraday and James Maxwell

6.2 PROGRESS OF SCIENCE AND TECHNOLOGY IN 18TH AND 19TH CENTURIES

As scientific developments started taking place all across Europe, it varied greatly from country to country. In Germany, pure science remained the main pursuit. German scientists continued to do research and experimentation. In England, scientists searched for the answer to practical problems. The need for better machines and devices was strengthened with the Industrial Revolution. Though universities such as Oxford and Cambridge strengthened the field of science, certain restrictions were still imposed upon by the Church of England who insisted that dissections should not be performed. Technological advancements accelerated in the United States. Most of the devices created focussed on minimal labour. Due to this need, some of America's most famous scientists were known for their inventions. To this day, Alexander Graham Bell, Thomas Edison, George Eastman and George Westinghouse are still recognized names.

The various sectors where developments took place are discussed as follows:

1. Textile industry

The British textile industry was based on wool processed by individual artisans. These artisans were engaged in weaving and spinning in the backyard of their homes. As this process gained momentum, gradually it came to be termed as the cottage industry. The cottage industry proved profitable for the merchants, as they were able to sell the finished goods at a better price in the market. England ended up exporting high-quality products across the globe. The success of the cottage industry boosted England's economy and changed the lives of many English people, both for the rural and the urban. Cotton and flax were the two main components used to spin cloth.

In the 1730s, Lewis Paul along with John Wyatt, a carpenter from Birmingham, designed a spinning machine, which came to be known as the Roller Spinning. They were also instrumental in designing the flyer-and-bobbin system, which helped in drawing wool to an even thickness. Consequently, the duo opened a mill in Birmingham using their roller spinning powered by a donkey. The success of the mill was instrumental in setting up a factory in Nottingham in 1743, which operated until 1764. Lewis's invention was later developed and improved by Richard Arkwright in his water frame and Samuel Crompton in his spinning mule in the late 1760s.

The years following witnessed many more inventions which, increased the efficiency of spinning thereby boosting the supply of yarn. An individual labourer's output increased manifold. A class of entrepreneurs, the most famous of them being Richard Arkwright capitalized upon these advances.

2. Metallurgy

The Reverberatory Furnace could produce wrought iron using mined coal. The burning coal remained separate from the iron ore and so did not contaminate the iron with impurities like sulphur. This opened the way to increased iron production.

The major transformation that took place in the metal industries during the Industrial Revolution was the replacement of organic fuels based on wood with fossil fuel based on coal. However, much of this happened little before the Industrial Revolution, based on innovations by Sir Clement Clerke and others from 1678, using coal reverberatory furnaces known as cupolas. These cupolas were operated upon by the flames containing carbon monoxide, playing on the ore and reducing the oxide to metal. One advantage of this method was that the impurities in the coal could not accumulate into the metal. Lead and copper were the two metals on which this method was applied from 1678 and 1687 onwards respectively. Later on in the 1690s, this method was applied to iron foundry and the furnace was referred to as an air furnace.

This was followed by Abraham Darby's experiments with coke to fuel his blast furnaces, at Coalbrookdale in 1709. However, the pig iron he made was used mostly for the production of cast iron goods such as pots and kettles. Despite that, he had the advantage over his rivals in that his products, were thinner and cheaper as compared to his rivals. Coke pig iron was rarely used to produce bar iron in forges until the mid 1750s, when his son Abraham Darby II built Horsehay and Ketley furnaces. Since cast iron was becoming cheaper and more plentiful, it also became an important material for building the innovative The Iron Bridge in 1778 by Abraham Darby III.

Matthew Boulton helped James Watt to get his business off the ground. He set-up a massive factory called the Soho Factory, in the Midlands.

New methods and processes such as stamping and potting were introduced in the following years. Henry Cort, an English ironmaster, started the puddling process, a technology that was used to extract steel from pig iron produced in a blast furnace. Gradually by 1785, the processes of potting and stamping also improved and came out of patent. A great expansion in the British iron ore industry was noticed and the new processes did not depend on the use of charcoal anymore. Until then, iron manufacturers of Britain were considerably dependant on imported iron from Russia and Sweden until 1720s. However, 1785 onwards Britain not only manufactured wrought iron consumer goods, but also became an exporter of the same. The production of steel, an expensive commodity used for cutting edges, also underwent considerable modifications. The crucible steel technique was developed by Benjamin Huntsman in the 1740s.

3. Developments in Mining and Steam Power

Some mining activity took place in England during the late Tudor Period. However, deep shaft mining began to develop only during the late 18th century, which rapidly

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grew throughout the 19th and the early 20th century when industrialization was at its height. Coal mining in Britain, particularly in South Wales started early. Shaft mining was done in some areas, but the limiting factor was the problem of removing water. It could be done by hauling buckets of water up the shaft or to a sough (a tunnel driven into a hill to drain a mine). In either case, the water had to be discharged into a stream or ditch at a level where it could flow away by gravity. The introduction of the steam engine greatly facilitated the removal of water and enabled shafts to be made deeper, facilitating more coal to be extracted. The adoption of James Watt's steam engine from the 1770s reduced the fuel costs of engines, making mines more profitable. The presence of firedamp in the mines made coal mining somewhat perilous. This was provided with certain degree of safety with Sir Humphry Davy's invention of the safety lamp in 1816. However, this degree of safety was short lived; firedamp explosions continued, and often casualties were reported.

4. Steam power

The invention of the steam engine was a breakthrough in the Industrial Revolution; however, for most of the period of the Industrial Revolution, the majority of industries still relied on wind and water power as well as horse-and man-power for driving small machines.

Thomas Savery, a military engineer, made a real attempt at industrial use in 1698. He constructed and patented in London a low-lift combined vacuum and pressure water pump, that generated about one horsepower (hp) and was used in numerous water works and tried in a few mines (hence its 'brand name', *The Miner's Friend*), but it was not a success since it was limited in pumping height and prone to boiler explosions.

The first successful steam power plant was introduced by Thomas Newcomen before 1712. Apparently, Newcomen conceived the Newcomen steam engine quite independently of Savery, but as the latter had taken out a very wide-ranging patent. Therefore, Newcomen and his associates were obliged to come to an arrangement with Savery, marketing the engine until 1733 under a joint patent. It seems that Newcomen's engine was based on Papin's experiments carried out 30 years earlier, which employed a piston and cylinder and one end of which was open to the atmosphere above the piston. Steam forming on the atmospheric pressure (all that the boiler could stand) was introduced into the lower half of the cylinder beneath the piston during the gravity-induced upstroke; the steam was then condensed by a jet of cold water injected into the steam space to produce a partial vacuum; the pressure differential between the atmosphere and the vacuum on either side of the piston displaced it downwards into the cylinder, raising the opposite end of a rocking beam to which was attached a gang of gravity-actuated reciprocating force pumps housed in the mineshaft. The downward power stroke of the engine raised the pump, priming it and preparing the pumping stroke. Initially the phases were hand controlled, but within a decade, an escapement

mechanism was devised which, worked through a vertical *plug tree* suspended from the rocking beam which rendered the engine self-active.

A number of Newcomen engines were successfully put to use in Britain for draining hitherto unworkable deep mines, with the engine on the surface; these were large machines, requiring a lot of capital to build, and produced about 5 hp (3.7 kW). They were extremely inefficient by modern standards, but when located where coal was cheap at pit heads, opened up a great expansion in coal mining by allowing mines to go deeper. Despite their disadvantages, Newcomen engines were reliable and easy to maintain and continued to be used in the coalfields until the early decades of the 19th century. By 1729, when Newcomen died, his engines had spread (first) to other European countries including Hungary, Germany, Austria, and Sweden. A total of 110 machines are known to have been built by 1733 when the joint patent expired. In the 1770s, engineer John Smeaton introduced a number of improvements. A total of 1,454 engines had been built by 1800.

By 1778, a fundamental change in working principles was brought about by James Watt in close collaboration with Matthew Boulton. Watt had succeeded in perfecting his steam engine, which incorporated a series of radical improvements, notably the closing off of the upper part of the cylinder thereby making the low pressure steam drive the top of the piston instead of the atmosphere; use of a steam jacket and the celebrated separate steam condenser chamber. These changes implied that a more constant temperature could be maintained in the cylinder and that engine efficiency no longer varied according to atmospheric conditions. These advancements increased engine efficiency by a factor of about five, saving 75 per cent on coal costs. In 1975, Boulton and Watt opened the Soho Foundry, for the manufacture of such engines.

However, by 1783 the Watt steam engine had been fully developed into a double-acting rotative type, which could be used to directly drive the rotary machinery of a factory or mill. Both of Watt's basic engine types were commercially very successful, and by 1800, the firm Boulton & Watt was established with 496 engines, 164 driving reciprocating pumps, 24 serving blast furnaces, and 308 powering mill machinery; most of the engines generated from 5 to 10 hp (7.5 kW).

The beam engine was the most common pattern of steam engine until 1800. But soon various patterns of self-contained portative engines such as the table engine was developed. By the beginning of the 19th century, the Cornish engineer Richard Trevithick, and the American, Oliver Evans began to construct higher-pressure non-condensing steam engines, exhausting against the atmosphere. This allowed an engine and boiler to be clubbed into a single unit compact enough to be used on road and rail locomotives and steam boats.

After the patent of Watt's steam engine expired, the machine underwent numerous modifications by a host of engineers and inventors.

5. Chemicals

An important progress of the Industrial Revolution was the large-scale production of chemicals. The first of these was the production of sulphuric acid by the lead chamber process invented by the Englishman John Roebuck in 1746. He was able to increase the scale of the manufacture by replacing the relatively expensive glass vessels with, less-expensive chambers made of riveted sheets of lead. Thus, he was able to make around 100 pounds (50 kg) in each of the chambers leading to at least a tenfold increase.

Gradually, there was an increase in the demand for other chemicals such as alkali as well. Nicolas Leblanc in 1791 succeeded in introducing a method for producing sodium carbonate. Named after its founder, the Leblanc process was a reaction of sulphuric acid with sodium chloride to give sodium sulphate and hydrochloric acid. Sodium sulphate was heated with limestone (calcium carbonate) and coal to give a mixture of sodium carbonate and calcium sulphide. Adding water separated the soluble sodium carbonate from calcium sulphide. Though this process caused immense pollution, nonetheless, this synthetic soda ash proved economical compared to previous processes of yielding soda ash.

These two chemicals turned out to be very significant because they were instrumental in bringing about a host of other inventions, replacing many small-scale operations with more cost-effective and controllable processes. Sodium carbonate had many uses in industries such as glass, textile, soap, and paper. Early uses for sulphuric acid included removing rust in iron and steel, and for bleaching cloth.

The other inventions and discoveries in the field of chemical science comprised development of bleaching powder (calcium hypochlorite) by Scottish chemist Charles Tennant in about 1800, based on the discoveries of French chemist Claude Louis Berthollet. Tennant's factory at St Rollox, North Glasgow, became the largest chemical plant in the world.

In 1824, a chemical process for making Portland cement was patented by Joseph Aspdin, a British bricklayer turned builder. This process involved sintering a mixture of clay and limestone to about 1,400 °C (2,552 °F), then grinding it into a fine powder, which is then mixed with water, sand and gravel to produce concrete. The famous English engineer Marc Isambard Brunel used the Portland cement several years later while constructing the Thames Tunnel. The same product was used on a large scale in the construction of the London sewerage system a generation later.

Post 1860, the focus shifted to dyestuffs, and Germany went on to become world leaders in the field of chemical science. Aspiring chemists flocked to German universities especially from 1860–1914 to learn the latest techniques.

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6. Machine tools

The Industrial Revolution would have been incomplete without the development of machine tools. It was these tools that made manufacturing possible. They have their origins in the tools developed in the 18th century by makers of clocks and watches and scientific instrument makers to enable them to batch-produce small mechanisms. The mechanical parts of early textile machines were sometimes called 'clock work' because of the metal spindles and gears they incorporated. The manufacture of textile machines drew artisan from these trades and is the origin of the modern engineering industry.

Various artisans were involved in making these machines such as carpenters constructed frames from wood and smiths and turners engaged themselves in making metal parts. A good example of how machine tools changed manufacturing took place in Birmingham, England, in 1830. The invention of a new machine by Joseph Gillott, William Mitcheland James Stephen Perry allowed mass manufacture of robust, cheap steel pen nibs; the process had been labourious and expensive. Since it was little difficult to manipulate metal, its use was kept to a minimum. Wood framing had the demerits of changing dimensions with temperature and humidity, and the various joints tended to rack (work loose) over time. Gradually, machines with metal frames gained popularity and the cylinder boring machine was the first machine that was used for boring cylinders on steam engines, which had large diameters.

The first half of the 19th century witnessed the development of various spinning machines such as the slotting machine, shaping machine and the planning machine. The milling machine had already been invented by now. However, it was only until the later part of the 19th century, that the milling machine was seriously developed as a workshop tool. The navy and the military of England was instrumental in developing machine tools. Henry Maudslay, trained at a school of machine tool makers, worked for Jospeh Bramah on the production of metal locks, and soon after he began working on his own. Maudslay was responsible for building the machinery for making ships' pulley blocks for the Royal Navy in the Portsmouth Block Mills for a short while. Maudslay exploited his skills to build machine tools. In his workshop, he trained people such as Richard Roberts, Joseph Clement and Joseph Whitworth, who further developed his works.

For the first third of the century, businessmen James Fox of Derby and Matthew Murray of Leeds had a healthy export trade in machine tools.

7. Gas lighting

Another major industry to be affected by the Industrial Revolution was the gas lighting industry. Though others made a similar innovation elsewhere, the large-scale introduction of this feature was witnessed through the work of William Murdoch, an employee of Boulton and Watt, the pioneers in steam engine, based out of Birmingham. The process consisted of large-scale gasification of coal in

furnaces, the purification of the gas (removal of sulphur, ammonia, and heavy hydrocarbons), followed by its storage and distribution. The first gas lighting utilities were established in London, between, 1812 and 1820 who very soon went on to become the major consumers of coal in Britain. The rapid expansion of the gas lighting industry had an impact on social and industrial organization since it allowed factories and stores to remain open until late evening. This allowed nightlife to flourish in cities and towns as interiors and streets could be lighted on a larger scale than before.

8. Glass making

A new method known as cylinder process used for producing glass was developed in the early 19th century. The Chance Brothers implemented this process in 1832, to create sheet glass. Gradually, they went on to become the leading producers of window and plate glass. This advancement allowed for larger panes of glass to be created without interruption, thus freeing up the space planning in interiors as well as the fenestration of buildings. The Crystal Palace is the supreme example of the use of sheet glass in a new and innovative structure.

9. Paper machine

In 1798, Nicholas Louis Robert patented a machine for making a continuous sheet of paper on a loop of wire fabric. He worked for Saint-Léger Didot family in France. The paper machine came to be known as a Fourdrinier after the financiers, brothers Sealy and Henry Fourdrinier, who were stationers in London. With the passage of time, though the machine underwent various transformations, the original Fourdriner machine still happens to be the predominant means of paper production till date.

10. Astronomy

Astronomy as a field of science started gaining momentum especially with the discovery of Uranus. The science of astronomy dealt mainly with the study of the solar system. Once Uranus was discovered, the curiosity of the astronomers was aroused. They took the help of mathematics to figure out the location of other planets.

Searching for other planets

In 1821, Uranus created ripples in the world of astronomy, when it was discovered that the planet was not travelling in its predicted orbit. Seven years later, in 1828, when Uranus travelled far away from its orbit; astronomers began searching for another planet. Astronomers used the Titus-Bode law and calculated that the new planet should be 38 times far away from the Sun than the Earth. Astronomers now focussed on this location with a telescope. Many more researches continued in this field. In 1845, British astronomer John Couch Adams and his French counterpart Jean de Verrier hypothetically concluded where the new planet could be found. Finally, German astronomer Johann Galle discovered the planet Neptune on 23 September 1846. Later, that year, Triton, Neptune’s satellite was uncovered.

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The end of the 19th century saw American scientist Percival Lowell beginning to search for a ninth planet. The astronomy of this era began with the Church lifting its ban on teaching Copernican system in 1821. The ban on Galileo's book that lasted for almost two centuries was also lifted.

The solar system

Astronomers spent a majority of their efforts to explain what they witnessed within the solar system. This began with the 2nd return of Halley's Comet in 1835. A solar eclipse followed this in 1836. While observing the solar eclipse, Francis Bailey saw bright spots along the moon's edge. These would come to be known as Bailey's Beads. The next year, Johann Enke saw a gap in Saturn's outer ring, much like the gap that Cassini saw which divided the rings. This gap in the outer ring was named after Enke. In 1845, Karl Hencke discovered the 5th and 6th asteroids, Astrea and Hebe. There still was some question as to what asteroids were. By 1860, the only thing astronomers were relative sure of was that asteroids were not a broken planet. Astronomy also experienced one of the first contributions by a woman. In 1847, Maria Mitchell discovered a comet on 1st October. This discovery called attention to the contributions of women in science.

Spectrometry was yet another advancement in the realm of astronomy. Ideas about light changing and use of light to find out what comprised stars came in 1848. Hippolyte Fizeau came up with the suggestion that light moving away from us shifted to the red. This he referred to as the red shift. The same idea was later used by Edwin Hubble to determine that the universe was expanding. American astronomer David Alter, in 1854 conducted a series of experiments that helped him determine that each element could be identified by its light spectrum. Later, astronomers would conduct a spectrograph of the sun. By 1863, it was concluded that the Sun was made of elements, which were to be found on the Earth; an inference that debunked the Greek notion, that the elements comprising stars are not available on Earth. Several other studies concluded that instead of the Sun rotating as a single body, it was only the region around the equator that rotated every 27.5 days and the regions near the poles rotated every 25 days.

Life on Mars

In 1877, Asaph Hall, an American astronomer, discovered two new satellites of Mars. These were named after the sons of the Greek God of War, that is, Ares. They were called Phobos (fear) and Deimos (terror). The discovery of these stars managed to intrigue Giovanni Schiaparelli and encouraged him to begin studying Mars. He noticed 'canals' and 'channels' on the surface of the planet Mars. Then followed his hypothetical conclusion that these canals brought water down from the polar ice caps. His observation resulted in the belief that Mars supported life. This belief continues to intrigue scientists and researchers to this day. Percival Lowell became one of the leading advocates of Martian life.

Studies on Moon

During this time, researches began to be conducted on the moon. Astronomers suggested that the craters on the moon's surface occurred due to collision with asteroids and other celestial bodies. They also debated over the formation of moon as a satellite. By 1879, the most common idea of where the moon came from was that the moon was formed from the Earth's material that had been thrown from the Earth while it was spinning rapidly. This idea remained the most common idea until the 1960s.

11. Geological Time Scale

Once, the discovery of various human species took place, scientists became curious about fossils. In order to carry out the observation, scientists created the geological time scale. The various fossils that could be found within the layers decided the divisions within the scale. Every time there was a major change in the types of fossils or in some cases, human tools were found, a new dividing line was created. Scientists named various ages depending upon the fossils, as Stone Age, Bronze Age and Iron Age to show the tools used by humans.

Catastrophes and the Age of the Earth

Human civilization began to be affected due to natural calamities which led scientists to the study of geology. William Buckland, an English geologist, wrote a book where he argued the time of Noah's flood. Buckland's work was followed by Georges Cuvier's catastrophe theory. Cuvier concluded that large groups of animals were extinct because of huge catastrophes. Later scientists studied about asteroids striking the Earth. That, human activities could affect the climate and can lead to catastrophes as well, was claimed by French scientist Jean Baptiste Fourier.

There were several scientists who were unwilling to accept the idea of a 'Young Earth'. Charles Lyell wrote *The Principles of Geology* in 1830, a book that became the leading geology text of the time. In fact, Lyell came to be recognized as the 'Darwin of Geology'. Darwin even referred to Lyell's book on his maiden voyage on the Beagle. Lyell, on the other hand, was opposed to Darwin's early idea of evolution, and later accepted evolution based on T.H Huxley's arguments. Lyell ambitious study showed that the Earth was hundred million years old. He was also the first to identify the Recent, Pliocene, Miocene, and Eocene periods in the history of the Earth. Louis Agassiz believed that the Earth was much older. He discussed the idea that an Ice Age with glaciers covered most of Europe during 1837. He first obtained a degree in medicine before becoming interested in fossil fish. He described more than 1,700 new species and went on to study glaciers. He studied boulder deposits and scratches on rocks, on the basis of which he theorized that the glaciers had occupied a sizeable chunk of North America and Asia. By 1840, Agassiz managed to give a description of the motions and deposits of glaciers as a confirmation of his ice age theories. Geologist, Thomas Chamberlin, later argued that there was not just one but several ice ages. Arnold

Escher von der Linth built on Agassiz's ideas and started studying the Alps. He identified structures in the Alps that appeared to be several layers of napkin-like rocks that extended into kilometres. These layers were folded over each other in the form of a napkin, making Linth call them 'nappes'.

In 1856, William Thomas Blanford found out that the conglomerate rocks discovered in India were the results of glacial activity. He realized that the ice ages occurred several times and affected the northern as well as southern hemispheres. At the end of the 19th century, Arthur Holmes dated various rock formations using radioactivity. He used radioactivity to establish that the Earth was about 4.6 billion years old.

Idea of Tectonic Plates

During the 19th century, studies began surrounding the tectonic plates when Mathew Fontaine Maury completed his chart of the Atlantic Ocean. He proved that the centre of the ocean was shallower than its edges. The Mid-Atlantic ridge was later discovered by scientists. In 1859, the elastic rebound theory was developed by Harry Reid. The idea of one fault rubbing against another, causing earthquakes, was propounded by this theory, which, debunked earlier beliefs. The first modern seismograph was invented by John Milne. Another scientist named Suess used the idea of moving plates to study formation of mountains.

6.2.1 Development of Biological Sciences

Biological sciences promote basic researches to explain the scientific support of clinical analysis and understand the system of recovery and adaptation. In the 18th and 19th centuries, biological sciences like botany and zoology gained popularity in the form of professional scientific disciplines. Antoine-Laurent de *Lavoisier* (also known as the father of modern chemistry) and other physical scientists began to make use of physical and chemical sciences to relate both animate and inanimate worlds. Explorer-naturalists such as Alexander von Humboldt (a German naturalist) examined the interface between organisms and the ecosystem and the dependence of this relationship on geography. He laid the foundations for biogeography, ecology and ethology. Naturalists started rejecting the theory of essentialism and considered extinction and the mutability of species as more significant. The fundamental platform of life got a new perception through cell theory. All these advancements, in addition to the outcome of embryology and palaeontology, were integrated in Charles Darwin's theory of evolution by natural selection. The latter part of the 19th century witnessed a fall in the spontaneity of generation and a rise in the germ theory of disease. However, the mechanism of inheritance was still not known.

The 18th century witnessed the following developments in the branch of biological sciences:

- The 18th century was a period marked by explorations, collections and organizations related to biological science. During this period, science was in a stage of transition.

- In the year 1700, only 6000 species of living organisms were identified. However, this figure rose to 50,000 in the year 1800.
- William Sherard was an English botanist who was the first dedicated taxonomist in history.
- Carolinus Linnaeus was a leading personality in the field of science during the 18th century. He invented and categorized the binomial system of classification (genus/species) for botany and zoology in a commendable way. In his ground-breaking work, *Systema Naturae* (1735), Linnaeus postulated that species could not be converted and were fixed.
- Georges-Louis Leclerc, Comte de Buffon was a French scientist who proposed that species are likely to undergo changes over time. He suggested the theory of common descent with concepts that turned out to be sources of great influence in the works of Lamarck and Darwin, during the 19th Century.
- In the New World (Western hemisphere), a significant amount of biological work was done by naturalists or physicians, who had received botanical training.
- Every issue of *Philosophical Transactions A* of The Royal Society published several scientific results. This was a journal dedicated to the subjects of mathematical, physical and engineering sciences.
- Learned societies began publishing their own scientific journals. By 1900, 10,000 scientific journals were being published. They stimulated the beginning of indexing and abstracting services.

The 19th century witnessed the following developments in the branch of biological sciences:

- French naturalist, Jean Baptiste Lamarck, initially used the term biology, in the beginning of the 19th century.
- The 19th century witnessed a number of new concepts related to the organization of cells. The germ theory of disease and evolution was the most prominent biological concept.
- Physiological processes were described with the help of chemistry and chemical processes.
- By the year 1880, more than 100 science journals were being published around the world.
- The foundation for the theory of evolution was laid by the works of Buffon, Darwin and Lamarck.
- At the time of the second voyage of H.M.S. Beagle (1831–1836), Charles Darwin conducted biological, geological and anthropological studies of southern lands and islands (including New Zealand, which he had visited in 1835). He collected material for his two famous books: *The*

Voyage of the Beagle (1839) and *On the Origin of Species - By Means of Natural Selection* (1859). In these books, he assembled his research on evolution by natural selection.

- The field work of Alfred Russel Wallace and Henry Walter Bates, in South America, offered more evidence for the theory of evolution, with Wallace's work (both there and later in the Malay Archipelago). This work gave results which were similar to those given by Darwin.
- German naturalist and explorer Alexander von Humboldt (considered an unparalleled scientific explorer of the world) collected specimens related to botany and zoology from South America. His collections added large amounts information on diverse and distributed species. In addition to the epic works of Wallace and von Humboldt, significant foundations were laid by *Kosmos* (1845) for the study of biogeography.
- Gregor Mendel, who was a Catholic monk, observed inherited traits in garden peas and published his journal, *Experiments on Plant Hybridization* (1866). The scientific community generally ignored this journal until 1900.
- After the American Revolution, America's relations with Britain and the Royal Society ceased to exist. There were not many American natural historians during this period.
- Field work (empirical rather than theoretical) was still the basis of science and America was going through a conflict between science and religion.
- Following the American Civil War (1861–65), American education underwent a restructuring. Universities like Harvard and Johns Hopkins were established on the basis of German laboratory and university models.
- In the latter part of the 19th century, there were several scientific institutes in the US. A large number of journals and societies also became socially approved.
- The publication of one of the world's foremost biological journals, *Nature (London)* began in 1869.
- The latter part of the 19th century witnessed significant developments in the palaeontology of vertebrates, in the US. Museums received vast collections of prehistoric species of animals, specifically dinosaurs and mammals from western America. This triggered a scientific argument on evolution and extinction.
- Natural history and natural philosophy were brought closer by the science of geology. On the other hand, geological stratigraphy linked the spatial and temporal distribution of organisms, a precursor to later theories of evolution.

- A well-known anatomist from France, Baron Georges Cuvier, compared fossil and living mammals in detail. He was wrong while claiming that all large vertebrates had already been identified.
- Gideon Mantell, Mary Anning, William Buckland and anatomist Richard Owen were famous for either discovering, or describing Mesozoic fossil reptiles. They showed that the Age of Reptiles (Mesozoic era) had existed before the present Age of Mammals (Cenozoic era).
- A large number of geologists of that era, followed the principles of the catastrophe theory (theory of studying and classifying phenomena characterized by sudden shifts in behaviour, caused as a result of small circumstantial changes).
- Charles Lyell's wrote a book titled, *Principles of Geology* (1830–33), which explained the steady and continuous nature of geological processes.

Check Your Progress

1. Name the prominent scientists of America known for their inventions during the 18^{th} and the 19^{th} centuries.
2. When was The Iron Bridge and by whom?
3. Who developed the crucible steel technique?
4. State one important feature of the Industrial Revolution.

6.3 DARWIN, FARADAY AND MAXWELL

In this section, you will learn about three important scientists of the 18th-19th centuries, namely Charles Darwin, Michael Faraday and James Clerk Maxwell.

6.3.1 Charles Darwin: Theory of Evolution

One of the greatest naturalist of all times, Charles Darwin, in his famous work *On The Origin Of Species By Means Of Natural Selection Or The Preservation Of Favoured Races In The Struggle For Life*, (1859) came up with his famous Theory of Evolution. He convinced many scientists of the validity of his theory through various examples. Some of them are discussed below.

Though the idea of evolution existed during the Greek civilization, it was only during the 1800s that it was strongly propounded. Darwin embarked on a trip to the Galapagos Islands as a crew scientist on the HMS Beagle in 1831. The journey lasted for five years and upon his return to his homeland, Darwin compiled his experiences in a journal titled *Journal of Researches into the Geology and Natural History of the Various Countries Visited by the HMS Beagle 1832–*

36. This book recorded Darwin's work on fossils, plants and animals and the geology discovered during his voyage. In 1842, Darwin would write a 35-page paper that would later become his theory of evolution. Finally, in 1858, Darwin along with Wallace, presented their theory of evolution to the Linnaean Society and to the public in 1859. In this book, Darwin, presents two distinct ideas, first, all species of life on Earth have arisen by evolution from other pre-existing species and second, was that the process that drives evolution is termed as natural selection. Some scientists like Louis Agassiz and Bishop Wilberforce disagreed with Darwin's theory of evolution and debates continued surrounding the same.

However, Darwin remained aloof from these debates and continued to write. In 1862, he wrote *The Various Contrivances by Which Orchids are Fertilized by Insects*, which explained how varieties of orchids had evolved in order to increase pollination. Darwin, still continued with his magnum opus the *Origin of Species* where he decided to take a look at human evolution. In his book, *The Decent Of Man and Selection in Relation To Sex* Darwin argued about the ideas of humans evolving from lower forms of life. The concept of sexual selection was also introduced in the same text. According to Darwin, sexual selection explained our lack of natural weapons. Darwin's ideas of evolution dominated the world of natural science while new discoveries began creating ripples in the world of biology.

6.3.2 Michael Faraday

Michael Faraday was a British chemist and physicist who contributed significantly to the study of electromagnetism and electrochemistry. Faraday was born on 22 September 1791 in south London. His family was not well off and Faraday received only a basic formal education. When he was 14 years of age, he was apprenticed to a local bookbinder and during the next seven years, educated himself by reading books on a wide range of scientific subjects. In 1812, Faraday attended four lectures given by the chemist Humphry Davy at the Royal Institution. Faraday subsequently wrote to Davy asking for a job as his assistant. Davy turned him down but in 1813 appointed him to the job of chemical assistant at the Royal Institution.

A year later, Faraday was invited to accompany Davy and his wife on an 18-month European tour, covering France, Switzerland, Italy and Belgium and meeting many influential scientists. On their return in 1815, Faraday continued to work at the Royal Institution, helping with experiments for Davy and other scientists. In 1821 he published his work on electromagnetic rotation (the principle behind the electric motor). He was able to carry out little further research in the 1820s, busy as he was with other projects. In 1826, he founded the Royal Institution's Friday Evening Discourses and in the same year the Christmas Lectures, both of which continue to this day. He himself gave many lectures, establishing his reputation as the outstanding scientific lecturer of his time.

In 1831, Faraday discovered electromagnetic induction, the principle behind the electric transformer and generator. This discovery was crucial in allowing electricity to be transformed from curiosity into a powerful new technology. During the remaining decade, he worked on developing his ideas about electricity. He was partly responsible for coining many familiar words including 'electrode', 'cathode' and 'ion'. Faraday's scientific knowledge was harnessed for practical use through various official appointments, including scientific adviser to Trinity House (1836-1865) and Professor of Chemistry at the Royal Military Academy in Woolwich (1830-1851).

However, in the early 1840s, Faraday's health began to deteriorate and he did less research. He died on 25 August 1867 at Hampton Court, where he had been given official lodgings in recognition of his contribution to science. He gave his name to the 'farad', originally describing a unit of electrical charge but later a unit of electrical capacitance.

6.3.3 James Clerk Maxwell

James Clerk Maxwell, an English scientist, developed a scientific theory to explain electromagnetic waves. He noticed that electrical fields and magnetic fields can couple together to form electromagnetic waves. Neither an electrical field (like the static which forms when you rub your feet on a carpet), nor a magnetic field (like the one that holds a magnet onto your refrigerator) will go anywhere by themselves. But, Maxwell discovered that a changing magnetic field will induce a changing electric field and vice-versa.

His discoveries helped usher in the era of modern physics, laying the foundation for such fields as special relativity and quantum mechanics. Many physicists regard Maxwell as the 19^{th} century scientist having the greatest influence on 20^{th} century physics. His contributions to the field of science are considered by many to be of the same magnitude as those of Isaac Newton and Albert Einstein. In the millennium poll—a survey of the 100 most prominent physicists—Maxwell was voted the third greatest physicist of all times, behind only Newton and Einstein. On the centenary of Maxwell's birthday, Einstein described Maxwell's work as the 'most profound and the most fruitful that physics has experienced since the time of Newton'. Einstein, when he visited the University of Cambridge in 1922, was told by his host that he had done great things because he stood on Newton's shoulders; Einstein replied: 'No I don't. I stand on the shoulders of Maxwell.'

Check Your Progress

5. Name the famous work of Charles Darwin in which he has explained his Theory of Evolution.
6. Mention one significant discovery of Michael Faraday.

6.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

NOTES

1. Alexander Graham Bell, Thomas Edison, George Eastman and George Westinghouse are the prominent scientists of America known for their inventions during the 18th and the 19th centuries.
2. The Iron Bridge was built in 1778 by Abraham Darby III.
3. The crucible steel technique was developed by Benjamin Huntsman in the 1740s.
4. An important feature of the Industrial Revolution was the large-scale production of chemicals.
5. Charles Darwin, in his famous work *On The Origin Of Species By Means Of Natural Selection Or The Preservation Of Favoured Races In The Struggle For Life*, (1859) came up with his famous Theory of Evolution.
6. In 1831, Faraday discovered electromagnetic induction which is considered to be one of his significant discoveries.

6.5 SUMMARY

- The 18th and 19th centuries (period of Industrial Revolution in Europe and the US) witnessed several changes in the field of science and technology, beginning with the textile industry, iron ore and then spreading to other sectors.
- As scientific developments started taking place all across Europe, it varied greatly from country to country.
- The British textile industry was based on wool processed by individual artisans. These artisans were engaged in weaving and spinning in the backyard of their homes.
- The Reverberatory Furnace could produce wrought iron using mined coal. The burning coal remained separate from the iron ore and so did not contaminate the iron with impurities like sulphur. This opened the way to increased iron production.
- Matthew Boulton helped James Watt to get his business off the ground. He set-up a massive factory called the Soho Factory, in the Midlands.
- The adoption of James Watt's steam engine from the 1770s reduced the fuel costs of engines, making mines more profitable. The presence of firedamp in the mines made coal mining somewhat perilous.
- The invention of the steam engine was a breakthrough in the Industrial Revolution; however, for most of the period of the Industrial Revolution, the majority of industries still relied on wind and water power as well as horse-and man-power for driving small machines.

- The first successful steam power plant was introduced by Thomas Newcomen before 1712. Apparently, Newcomen conceived the Newcomen steam engine quite independently of Savery, but as the latter had taken out a very wide-ranging patent.
- By 1778, a fundamental change in working principles was brought about by James Watt in close collaboration with Matthew Boulton.
- An important progress of the Industrial Revolution was the large-scale production of chemicals. The first of these was the production of sulphuric acid by the lead chamber process invented by the Englishman John Roebuck in 1746.
- The Industrial Revolution would have been incomplete without the development of machine tools. It was these tools that made manufacturing possible. They have their origins in the tools developed in the 18th century by makers of clocks and watches and scientific instrument makers to enable them to batch-produce small mechanisms.
- The first half of the 19th century witnessed the development of various spinning machines such as the slotting machine, shaping machine and the planning machine. The milling machine had already been invented by now.
- Another major industry to be affected by the Industrial Revolution was the gas lighting industry. Though others made a similar innovation elsewhere, the large-scale introduction of this feature was witnessed through the work of William Murdoch, an employee of Boulton and Watt, the pioneers in steam engine, based out of Birmingham.
- A new method known as cylinder process used for producing glass was developed in the early 19th century. The Chance Brothers implemented this process in 1832, to create sheet glass.
- Astronomy as a field of science started gaining momentum especially with the discovery of Uranus.
- Spectrometry was yet another advancement in the realm of astronomy. Ideas about light changing and use of light to find out what comprised stars came in 1848.
- In 1877, Asaph Hall, an American astronomer, discovered two new satellites of Mars. These were named after the sons of the Greek God of War, that is, Ares.
- Once, the discovery of various human species took place, scientists became curious about fossils. In order to carry out the observation, scientists created the geological time scale.
- There were several scientists who were unwilling to accept the idea of a 'Young Earth'. Charles Lyell wrote *The Principles of Geology* in 1830, a book that became the leading geology text of the time.

- In 1856, William Thomas Blanford found out that the conglomerate rocks discovered in India were the results of glacial activity.
- Biological sciences promote basic researches to explain the scientific support of clinical analysis and understand the system of recovery and adaptation.
- One of the greatest naturalist of all times, Charles Darwin, in his famous work *On The Origin Of Species By Means Of Natural Selection Or The Preservation Of Favoured Races In The Struggle For Life*, (1859) came up with his famous Theory of Evolution.
- In 1862, he wrote *The Various Contrivances by Which Orchids are Fertilized by Insects*, which explained how varieties of orchids had evolved in order to increase pollination.
- Michael *Faraday was a British chemist and physicist who contributed significantly to the study of electromagnetism and electrochemistry.*
- In 1831, Faraday discovered electromagnetic induction, the principle behind the electric transformer and generator.
- James Clerk Maxwell, an English scientist, developed a scientific theory to explain electromagnetic waves. He noticed that electrical fields and magnetic fields can couple together to form electromagnetic waves.

6.6 KEY WORDS

- **Shaft mining:** It is is **a** type of mining process used to vertically gain access to an underground mining facility.
- **Astronomy:** It refers to the scientific study of the universe and of objects that exist naturally in space.
- **Spectrometry:** It refers to the observation and measurement of wavelengths of light or other electromagnetic radiation.
- **Seismograph:** It is an instrument that makes a record of seismic waves caused by an earthquake, explosion.
- **Capacitance:** It is the ratio of the amount of electric charge stored on a conductor to a difference in electric potential.

6.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Write short notes on the significant developments which took place during the Industrial Revolution in the following fields:

   (a) Chemicals (b) Metallurgy

2. Mention the significant developments which took place in the field of Biological sciences during the Industrial Revolution.
3. What was James Clerk Maxwell's contribution in the field of modern physics?

Long-Answer Questions

1. Examine the significance of the invention of the steam engine was a breakthrough in the Industrial Revolution.
2. Describe the usage of various machine tools which emerged during the Industrial Revolution.
3. 'Astronomy as a field of science started gaining momentum especially with the discovery of Uranus.' Elucidate the statement.
4. Discuss the implications of the discovery of the Theory of Evolution by Charles Darwin.
5. Explain Michael Faraday's contribution in the field of *electromagnetism and electrochemistry.*

6.8 FURTHER READINGS

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BLOCK - III
SCIENCE AND TECHNOLOGY IN THE 17TH AND 18TH CENTURIES

UNIT 7 SCIENCE AND TECHNOLOGY IN THE 17TH AND 18TH CENTURIES-I

Structure

7.0 INTRODUCTION

The 18th century marked the beginning of the first phase of the Industrial Revolution. It was also part of the 'The Age of Enlightenment,' a historical period characterized by a transition from traditional religious forms of authority towards science and rational thought. However, it was not until the latter half of the 19th century that science was able to provide important help to industry. It was in the 19th century that the sub-microscopic world of material atoms became comprehensible. Beginning with Dalton's atomic theory, the chemists were able to recognize increasing number of elements and to formulate laws describing their interactions. Mendeleev devised a periodic table in which order was established by arranging the elements according to their atomic weights and their reactions. Significant advancements were made in the field of medical science. James Simpson experimented with different chemicals and found that chloroform was an effective anaesthetic. Edward Jenner became famous for his innovative contribution to immunization and eradication of smallpox.The most dramatic revolution in the field of biology in the 19th century was the one created by the germ theory of disease, championed by Louis Pasteur in France.

NOTES

7.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the life history and contribution of John Dalton in the field of chemistry
- Examine the role of Mendeleev in devising the periodic table
- Describe the life and contribution of James Simpson in the field of medical science
- Assess the role of Edward Jenner in the immunization and eradication of smallpox disease
- Discuss about the life and contribution of Louis Pasteur in the development of medical sciences

7.2 JOHN DALTON

John Dalton was a chemist, physicist and meteorologist who was born at Eaglesfield, a village in Cumberland, England. He was the son of a poor weaver. He received his early education from his father and from Quaker John Fletcher, who ran a private school in the nearby village. In 1776, he entered the service of a wealthy Quaker Elihu Robinson. His intellect or scientific knowledge convinced the authorities of his competence. In 1781, he joined his elder brother in running a school in Kendal, Westmorland. There he met John Gough, a blind philosopher, who encouraged him to study languages and mathematics. In 1793, Dalton was appointed as Professor of Mathematics and Natural philosophy in New College, Manchester. He showed great fondness for mathematics and was always looking for solution to mathematical problems. He gradually felt that he needed more time and freedom for his pursuit of aerology and resigned in 1799 from this job to become a private tutor.



Fig 7.1 *John Dalton*

Source: https://commons.wikimedia.org/wiki/File:John_Dalton.jpeg

In his early life, Dalton was influenced by Elihu Robinson who was a competent meteorologist and instrument maker. Dalton used to take observations of the atmosphere and weather as a hobby. In 1787, he began his meteorological diary. He kept meticulous records of weather observations of the last 46 years before his death. He rediscovered George Hadley's theory of atmospheric circulation. Besides this, he was involved in constructing crude thermometers, barometers and hydrometers. As a Quaker, Dalton lived a modest and unassuming personal life. He shunned away from any form of glory. He refused to be nominated for the membership of the Royal Society in 1810. He had to be quietly elected in 1822.

Prominent scientists such as Priestley, Cavendish and Lavoisier had exhibited that air was composed of oxygen, nitrogen, carbon dioxide and water vapours. However, it was not known as to whether air was a chemical compound or a mixture. Dalton showed that air was a mechanical mixture though it was known from experiments to have a constant composition. He explained this by saying that the gases could diffuse through each other, thus keeping the composition of the air as constant.

The most important of all investigations of John Dalton are associated with the atomic theory of chemistry. He arrived at this atomic theory on the basis of speculation on the physical properties of gases. He did not feel that experimental proof was always absolutely essential. Dalton trusted his brain more than his hands. In 1808, John Dalton forwarded a hypothesis which can be stated as follows:

- (i) Matter is discrete and consists of extremely small particles called atoms which are incapable of further subdivision.
- (ii) Atoms of the same element are similar to one another in all respects.
- (iii) Atoms of different elements have different properties and possess different weights.
- (iv) Combination between atoms takes place in simple ratios to form compound atoms (modern molecules).
- (v) Atoms can neither be created nor destroyed by any physical or chemical means.

Dalton had observed that elements might combine in different proportions to produce different compounds, but each compound followed the law of definite proportions. He calculated the relative weights of the atoms of various elements as compared with an atom of hydrogen. These are nothing but atomic weights. Dalton prepared a table of atomic weights. He observed that carbon dioxide is composed of carbon and oxygen in the ratio 3: 8 and carbon monoxide is made up of carbon and oxygen in the ratio 3:4. Thus, carbon dioxide has just twice the oxygen that carbon monoxide has. Dalton found such cases in the methane (carbon: hydrogen 3:1) and ethane (carbon: hydrogen: 6:1). Similar observations were made with oxides of nitrogen. On the basis of these observations, Dalton propounded the

Law of Multiple Proportion. In 1808, Dalton published a book *New System of Chemical Philosophy* in which he described all his theories.

Dalton gave a theoretical structure of atomic theory. Following his theory, other scientists provided it an experimental basis by their accurate analysis. John Dalton died on 27 July 1844 in Manchester after rendering meritorious service to chemistry. His atoms occupy a venerable position in the science of today. Dalton is regarded as the father of modern chemistry.

7.3 DMITRI MENDELEEV

Dmitri Mendeleev was a Russian chemist who was born on 8 February 1834 at Verkhnie Aremzyani, near Tobolsk in Siberia to Ivan Pavlovich Mendeleev and Maria Dmitrievna Mendeleeva. Ivan was a school principal who later became blind and lost his job and Maria was forced to work. After Ivan's death, Maria took Mendeleev to Moscow in 1849 with the objective of getting him enrolled at the Moscow University. However, he was denied admission there. He then entered the Main Pedagogical Institute at St. Petersburg in 1850. His mother died soon after, and Mendeleev graduated in 1855. After graduation, he contracted tuberculosis which caused him to move to Crimea. While there he got his first teaching position at 1st Simferopol Gymnasium. He returned to St. Petersburg to continue his education. He got his master's degree in 1856 and started conducting research in organic chemistry. Mendeleev received a government fellowship and he went to study abroad for two years at the University of Heidelberg. Here he established a laboratory in his own apartment. He attended the International Chemistry Congress in Karlsruhe in 1860 which was convened to discuss important issues such as atomic weights, chemical symbols and chemical formulas. There he came into contact with many of the leading chemists of Europe. In later years, Mendeleev would especially remember a paper circulated by the Italian chemist Stanislao Cannizzaro that explained the notion of atomic weights.

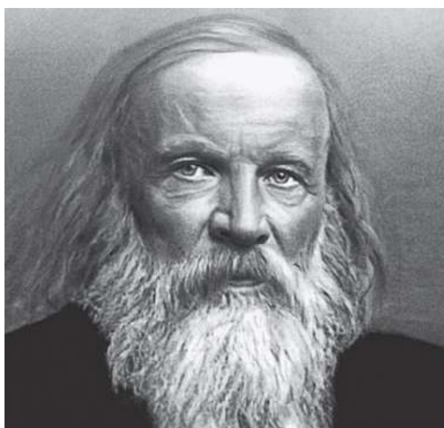


Fig 7.2 *Mendeleev*

Source:https://commons.wikimedia.org/wiki/File:Dmitri_Mendeleev.jpg

Mendeleev returned to St. Petersburg in 1861, where he obtained a professorship at the Technical Institute in 1864. After the defence of his doctoral dissertation in 1865, he was appointed as Professor of Chemical Technology at the University of St. Petersburg. He became Professor of general chemistry in 1867 and continued to teach there until 1890.

As he began to teach inorganic chemistry, Mendeleev recognized that there was no contemporary textbook on modern organic chemistry. He had already published a textbook on organic chemistry in 1861 that had been awarded the prestigious Demidov Prize. He set out to write another one. The result was *Osnovy khimii* (*The Principles of Chemistry*), which became a standard text for this field until early in the 20th century. In this book, he set out to organize and explain the elements. When Mendeleev started writing the chapter on the halogen elements (chlorine and its analogs), he compared the properties of this group of elements to those of the group of alkali metals such as sodium. Within these two groups of dissimilar elements, he discovered resemblances in the progression of atomic weights, and he wondered if other groups of elements showed similar properties. After studying the alkaline earths metals, Mendeleev established that the order of atomic weights could be used not only to arrange the elements within each group but also to arrange the groups themselves. Thus, in his attempt to make sense of the extensive knowledge that already existed of the chemical and physical properties of the chemical elements and their compounds, Mendeleev discovered the periodic law.

On 5 March 1869 Mendeleev made a formal presentation before the Russian Chemical Society titled *The Dependence between the Properties of the Atomic Weights of the Elements*, which described elements according to both atomic weight and valence. Mendeleev's periodic law states that the properties of elements are the periodic function of their relative atomic masses. This allowed him to build an organized table of all the 70 elements which were known at that time. He was so confident of the authenticity of the periodic law that he suggested changes to the generally accepted values for the atomic weight of a few elements and predicted the locations within the table of unknown elements along with their properties. Initially, the periodic system did not raise interest among chemists. Some people even dismissed Mendeleev for predicting that there would be more elements. However, he was proven correct with the discovery of the predicted elements, particularly gallium in 1875, scandium in 1879, and germanium in 1886. One of the unique features of Mendeleev's table was the gaps he left. In these places, he not only predicted there were as-yet-undiscovered elements, but he also predicted their atomic weights and their characteristics. Gradually, the periodic law and table became the framework for a great part of chemical theory. The original draft made by Mendeleev would be found years later and published under the name *Tentative System of Elements.* Mendeleev is regarded as the father of periodic table.

Mendeleev made other important contributions to chemistry. He was one of the founders of the Russian Chemical Society. He made significant contributions to the determination of the nature of indefinite compounds such as solutions. He is also given credit for the introduction of the metric system to the Russian Empire. He invented *pyrocollodion*, a kind of smokeless powder based on nitrocellulose.

Mendeleev died in 1907 at the age of 72 in St. Petersburg from influenza. He enjoyed international recognition and received many distinctions and awards from many countries.

7.4 JAMES SIMPSON

Sir James Young Simpson was a Scottish obstetrician who was born at Bathgate in Linlithgowshire on 7 June 1811 to David Simpson and Mary Jervais. He received his early education from the local school and in 1825 he enrolled in the University of Edinburg as an arts student and two years later he began his medical studies at the university. In April 1830, Simpson passed his exams at the College of Surgeons. In 1831, he enrolled in extramural classes on obstetrics and assisted in the work of Edinburgh's Royal Dispensary for the Poor. In October 1831, Simpson was appointed assistant to the director of the Dispensary, Dr W.T. Gairdner. He completed his MD thesis on inflammation in 1832.

In 1835, Simpson joined John Thomson, Professor of Pathology and his mentor, on a tour of Europe, visiting the top medical schools of London, Paris and Belgium. After returning to Edinburgh, he quickly established his own private practice in general medicine and obstetrics. By 1839, Simpson's practice was rapidly growing in the direction of obstetrics. His skills in obstetrics surpassed every other contemporary obstetrician. Simpson's services as gynecologist were also in high demand. He quickly caught the attention of the nobility and royalty. In 1843, Simpson left the Church of Scotland and joined the new Free Church of Scotland.



Fig 7.3 *James Simpson*

Source:https://commons.wikimedia.org/wiki/Category:James_Young_Simpson#/media/File:James_Young_Simpson_-_Project_Gutenberg_eText_13103.jpg

Anaesthesia was a new development in the medical profession at that time and Simpson quickly recognized its significance. He had always been concerned with the issue of pain during surgical operations and started experimenting with probable solutions. After news of the use of ether in surgery reached Scotland in 1846, he successfully used it in obstetrics, but was not satisfied. So he began searching for new forms of anaesthetic. Chloroform had already been invented in 1831, but its uses had not been deeply investigated. So Simpson first demonstrated the properties of chloroform upon humans, during an experiment with friends in which he learnt that it could induce one to sleep. Later, he substituted chloroform for ether and published his classic Account of a New Anaesthetic Agent. Simpson continued the use of chloroform for relief of labour pains, much against opposition from obstetricians and the clergy. Many viewed pain during childbirth as natural. Simpson ignored these objections and insisted on using chloroform during regular childbirth. Simpson received many honours and praises for his discovery associated with chloroform and in 1850 his position in Edinburgh was heightened by various prestigious appointments. On 7 April 1853 Queen Victoria gave birth to her eighth child with the successful administration of chloroform. This silenced all his critics and his standpoint on pain-free childbirth. Thus, chloroform became the anaesthetic choice for general surgery and Simpson must be attributed with the discovery of the use of chloroform as an anaesthetic. It was his readiness to explore the possibilities of the substance that set him on the road to a career as a pioneer in the field of medicine.

Other contributions of Simpson include introduction of iron wire sutures and acupressure, a method of stopping haemorrhage, and developing the long obstetrics forceps that were named after him. He is also known for his writings on medical history (particularly on leprosy in Scotland) and on foetal pathology and hermaphroditism.

Simpson was given the rank of baronet in 1866. In 1869 he took up the cause by promoting the rights of women to enter the medical field. He persuaded the Medical Faculty to allow Sophia Jex-Blake 'to attend the class of any professor who was willing to teach her.' Simpson peacefully died at his home in Edinburgh 6 May 1870 at the age of 58.

7.5 EDWARD JENNER

Edward Jenner was an English surgeon and discoverer of vaccination for smallpox. He was born on 17 May 1749 at Berkeley, Gloucestershire in England. He was born at a time when the patterns of British medical practice and education were undergoing gradual change. His father, the Reverend Stephen Jenner, was the vicar of Berkeley, so Jenner received a strong basic education. He went to school in Wotton-under-Edge at Katherine Lady Berkeley's School and in Cirencester. During this time, he was vaccinated for smallpox, which had a lifelong

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effect upon his general health. He was apprenticed for seven years to Daniel Ludlow, who was a surgeon of Chipping Sodbury, South Gloucestershire, where he gained experience needed to become a surgeon. In 1770, he became apprenticed in surgery and anatomy under surgeon John Hunter at a hospital in London. He became the most prominent surgeon in London. He was a top rank anatomist, biologist and experimentalist. He not only collected biological specimens, but also dealt with the problems of physiology and function.

Apart from practicing medicine, he became the member of two medical groups for the promotion of medical knowledge and wrote medical research papers. He made many observations, particularly on the nesting habits of the cuckoo and on bird migration. He also collected specimens for Hunter. Jenner married Catherine Kingscote in 1788.



Fig 7.4 *Edward Jenner*

Source:https://commons.wikimedia.org/wiki/File:Edward_Jenner_ by_James_Northcote.jpg

In 1792, Jenner earned his MD from the University of St. Andrews. He is credited with evolving the understanding of angina pectoris. In the 18th century, smallpox was rampant and occasional outbreaks led to a very high rate of mortality. The disease respected no social class, and deformity was not uncommon in patients who recovered. The only means of combating smallpox was a primitive form of vaccination called variolation—deliberately infecting a healthy person with the 'matter' taken from a patient sick with a mild attack of the disease. The practice, which originated in China and India, was based on two different concepts: first, that one attack of smallpox successfully protected against any subsequent attack and, second, that a person intentionally infected with a mild case of the disease would develop antibodies against it. However, the transmitted disease did not always remain mild, and sometimes mortality occurred. Moreover, the inoculated person could transmit the disease to others due to their becoming carriers of the disease.

Jenner observed that milkmaids were generally immune to smallpox. He postulated that the pus in the blisters that milkmaids received from cowpox (a

disease similar to smallpox, but relatively harmless) protected them from smallpox. Thus, Jenner concluded that cowpox not only protected against smallpox but could be transmitted from one person to another as an intentional mechanism of protection. In May 1796 Jenner found a young dairymaid, Sarah Nelmes, infected with cowpox. He inoculated an 8 year old boy, James Phipps, who never suffered from smallpox using matter from Sarah's lesions. Phipps slightly got ill for the next 9 days but was well on the 10th day. In July Jenner inoculated the boy again, this time with smallpox matter. No disease followed. Thus, protection was complete. In 1798, Jenner privately published a book entitled *An Inquiry into the Causes and Effects of the Variolae Vaccinae*.

However, there were numerous complications. Vaccination appeared simple, but the vast number of persons who practiced it did not essentially follow the procedure suggested by Jenner and deliberate or unconscious innovations often impaired the effectiveness of vaccination. It was not an easy task to acquire pure cowpox vaccine and nor was it easy to preserve or transmit it. Moreover, the biological factors that produced immunity were not yet fully understood. Considerable information had to be accumulated and a number of mistakes were made prior to the development of a completely efficient procedure.

In spite of errors and occasional deception, the death rate from smallpox plunged. Jenner received worldwide recognition and many honours, but he did not try to enrich himself through his discovery and actually devoted so much time to the cause of vaccination that his private practice and personal affairs suffered severely. His wife, ill with tuberculosis, died in 1815 and Jenner retired from public life. He died of a stroke on 26 January 1823 at the age of 73. Eventually in 1840, the British government banned variolation and provided free vaccination using cowpox. Edward Jenner is known as the father of Immunology.

7.6 LOUIS PASTEUR

Louis Pasteur was a French chemist and microbiologist who was born on 27 December 1822 in Dole, Jura, France to Jean Joseph Pasteur and Jeanne Etiennette Roqui. The family shifted to Marnoz in 1826 and then to Arbois in 1827. Pasteur joined the primary school in 1831 and attended secondary school at the college d'Arbois. He entered the College Royal at Besancon and passed his degree in 1840. He was appointed as a tutor at this college while continuing a degree science course with special mathematics. He passed the General Science Degree in 1842 from Dijon with a mediocre grade in chemistry. In 1846, he was appointed as Professor of Physics at the College de Tournon in Ardeche. In 1848, he became the Professor of Chemistry at the University of Stasbourg and became the chair of chemistry in 1852.I n 1854, he became the Dean of the new faculty of sciences at University of Lille, where he began his studies on fermentation. He moved to Paris in 1857 as the Director of scientific studies at the *École Normale Supérieure* and introduced a number of reforms to improve the standard of scientific work.

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Fig 7.5 *Louis Pasteur*

Source:https://commons.wikimedia.org/wiki/File:-Louis_Pasteur-_CIPC0023.jpg

He joined as a Professor of geology, physics, and chemistry in 1863 at the *École nationale supérieure des Beaux-Arts*, but resigned in 1867. Then he became the chair of organic chemistry at the Sorbonne. On his request the École Normale's laboratory of physiological chemistry was created in 1867. He was the laboratory's director from 1867 to 1888. In 1887, he established the Pasteur Institute in Paris, in which he was its director for the rest of his life.

Pasteur discovered the existence of molecular asymmetry, the foundation of stereochemistry, as it was revealed by optical activity. He further explored the ability of organic substances to rotate the plane of polarized light. He also examined the relationship that existed between crystal structure and molecular configuration. His studies convinced him that asymmetry was one of the fundamental characteristics of living matter.

Pasteur laid the foundation of the science of microbiology on a firm footing. Pouchet stated that air everywhere could cause spontaneous generation of living organisms in liquids. Pasteur conducted many experiments to disprove spontaneous generation. He presented experimental evidence for the participation of living organisms in all fermentative processes and showed that a specific organism was associated with every fermentation process. This evidence gave rise to the germ theory of fermentation or disease.

In his experiments, Pasteur heated the infusion material in the absence of air in a flask and observed that no organisms grew in it. Some people raised an objection that heating altered the composition of the infusion material. He broke the neck of the flask and found that micro-organisms settled in the flask and began to multiply. He performed similar experiments in the city, countryside and on high mountains. It was thus established beyond doubt that it is not the oxygen but the impurities (microbes) in the air which are responsible for causing fermentation. He

discovered that the process of fermentation could be arrested by passing air (i.e. oxygen) through the fermenting material, a process called Pasteur Effect. He arrived at the conclusion that this was due to the presence of microbes that could function only in the absence of oxygen. He introduced the terms aerobic and anaerobic to designate organisms that live in the presence or absence of oxygen respectively.

Pasteur established that fermentation, decomposition and putrefaction were all brought out by life. He applied his knowledge of microbes and fermentation to the wine and beer industries in France by saving the industries from collapse due to problems related to its production and with contamination that occurred during export. He showed that wine contamination is caused by microbes. So in order to prevent its contamination, he heated wine to 50-60°C, a process termed as pasteurization. Today, it is applied to many foods and beverages, especially milk.

Pasteur's manifold studies of the disease of silkworms, helped in preventing the main French silkworm industry. In 1879, he exhibited that the cause of puerperal fever in women was caused by a microbe which was carried by the unclean and infected hands of the doctors to the delivering mothers.

Pasteur discovered a vaccine to cure chicken cholera, and another for anthrax (a fatal disease of sheep and cattle). However, his most remarkable contribution has been towards developing a method of protecting human beings bitten by mad dogs, from preventing rabies (hydrophobia). Rabies was a dreaded and horrible disease that had captivated popular imagination for centuries because of its enigmatic origin and the fear it caused. For this, he took out the spinal cords of the animals in which he had experimentally produced the rabies and prepared the attenuated vaccines of different strengths. On 6 July 1885 Pasteur for the first time vaccinated nine-year-old Joseph Meister, who had been bitten by a dog who had rabies and had no chances of survival. It was a grand success since the child survived to lead a perfectly healthy life. Thereafter, Pasteur treated more patients. Due to his study of germs, Pasteur encouraged the surgeons to sanitize their hands and instruments prior to surgery.

An international fund-raising campaign was launched to build the Pasteur Institute in Paris and it was inaugurated on 14 November 1888. Pasteur died of a brain stroke on 28 September 1895 near Paris.

Check Your Progress

1. Who is regarded as the father of modern chemistry?
2. Who discovered the periodic law?
3. In which year was chloroform invented?
4. When was Simpson given the rank of baronet?
5. Who laid the foundation of the science of microbiology?
6. Define pasteurization.

7.7 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

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1. John Dalton is regarded as the father of modern chemistry.
2. Mendeleev discovered the periodic law.
3. Chloroform was invented in the year 1831.
4. Simpson was given the rank of baronet in the year 1866.
5. Pasteur laid the foundation of the science of microbiology.
6. Pasteurization is the partial sterilization of a product, such as milk or wine, to make it safe for consumption and improve its shelf life.

7.8 SUMMARY

- John Dalton was a chemist, physicist and meteorologist who was born at Eaglesfield, a village in Cumberland, England. He was the son of a poor weaver.
- In his early life, Dalton was influenced by Elihu Robinson who was a competent meteorologist and instrument maker. Dalton used to take observations of the atmosphere and weather as a hobby.
- The most important of all investigations of John Dalton are associated with the atomic theory of chemistry. He arrived at this atomic theory on the basis of speculation on the physical properties of gases.
- Dalton gave a theoretical structure of atomic theory. Following his theory, other scientists provided it an experimental basis by their accurate analysis.
- Dmitri Mendeleev was a Russian chemist who was born on 8 February 1834 at Verkhnie Aremzyani, near Tobolsk in Siberia to Ivan Pavlovich Mendeleev and Maria Dmitrievna Mendeleeva.
- After the defence of his doctoral dissertation in 1865, he was appointed as Professor of Chemical Technology at the University of St. Petersburg. He became Professor of general chemistry in 1867 and continued to teach there until 1890.
- On 5 March 1869 Mendeleev made a formal presentation before the Russian Chemical Society titled *The Dependence between the Properties of the Atomic Weights of the Elements*, which described elements according to both atomic weight and valence.
- Mendeleev made other important contributions to chemistry. He was one of the founders of the Russian Chemical Society. He made significant contributions to the determination of the nature of indefinite compounds such as solutions.

- In 1835, Simpson joined John Thomson, Professor of Pathology and his mentor, on a tour of Europe, visiting the top medical schools of London, Paris and Belgium.
- Anaesthesia was a new development in the medical profession at that time and Simpson quickly recognized its significance. He had always been concerned with the issue of pain during surgical operations and started experimenting with probable solutions.
- Other contributions of Simpson include introduction of iron wire sutures and acupressure, a method of stopping haemorrhage, and developing the long obstetrics forceps that were named after him. He is also known for his writings on medical history (particularly on leprosy in Scotland) and on foetal pathology and hermaphroditism.
- In 1792, Jenner earned his MD from the University of St. Andrews. He is credited with evolving the understanding of angina pectoris. In the 18th century, smallpox was rampant and occasional outbreaks led to a very high rate of mortality.
- Jenner observed that milkmaids were generally immune to smallpox. He postulated that the pus in the blisters that milkmaids received from cowpox (a disease similar to smallpox, but relatively harmless) protected them from smallpox.
- Louis Pasteur was a French chemist and microbiologist who was born on 27 December 1822 in Dole, Jura, France to Jean Joseph Pasteur and Jeanne Etiennette Roqui. The family shifted to Marnoz in 1826 and then to Arbois in 1827.
- He joined as a Professor of geology, physics, and chemistry in 1863 at the *École nationale supérieure des Beaux-Arts*, but resigned in 1867.
- In his experiments, Pasteur heated the infusion material in the absence of air in a flask and observed that no organisms grew in it. Some people raised an objection that heating altered the composition of the infusion material.

7.9 KEY WORDS

- **Anesthesia:** It is a state of controlled, temporary loss of sensation or awareness that is induced for medical purposes.
- **Atomic Weight:** It is the average mass of an atom of an element as it occurs in nature that is expressed in atomic mass units.
- **Obstetrics:** It is the field of study concentrated on pregnancy, childbirth and the postpartum period.
- **Stereochemistry:** It is the branch of chemistry dealing with the 3-dimensional arrangement of atoms and molecules and the effect of this on chemical reactions.

- **Vaccination:** It is the administration of a vaccine to help the immune system develop protection from a disease.

7.10 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Write a short note on the life of John Dalton.
2. Mention the significant events of the life of James Simpson.
3. What is known as the Pasteur Effect?

Long-Answer Questions

1. 'The most important of all investigations of John Dalton are associated with the atomic theory of chemistry.' Elucidate the statement.
2. What were Mendeleev's significant contributions in the field of chemistry?
3. Discuss the experiments of James Simpson for the use of chloroform as anaesthesia in the field of medicine.
4. Explain the contribution of Edward Jenner in the field of medicine.
5. 'Pasteur established that fermentation, decomposition and putrefaction were all brought out by life.' Discuss.

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UNIT 8 SCIENCE AND TECHNOLOGY IN THE 17TH AND 18TH CENTURIES-II

Structure

8.0 INTRODUCTION

Sigmund Freud was one of the most influential scientists of the late 18th and early 20th century in the fields of psychology and psychiatry. He developed the psychoanalytic theory according to which personality develops through a series of stages, each characterized by a certain internal psychological conflict.

The Industrial Revolution started in England in about 1750. The 18th century witnessed the transformation of technology from small-scale handicraft activity to a mechanized industrial system. It was the beginning of machine age. There was substitution of machines for tools. The British textile industry drove the Industrial Revolution, prompting advancements in technology, encouraging the coal and iron industries, enhancing import of raw material and improving transportation. The steam engine developed by Scottish inventor James Watt was one of the driving forces of the Industrial Revolution because prior to the18th century, the invention of machines had made little progress owing to the difficulty of finding a good motive power.

8.1 OBJECTIVES

After going through this unit, you will be able to:

- Assess the life history and contribution of Sigmund Freud in the field of psychology and psychiatry

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- Discuss the technological progress made in the field of textile industry in the 18th and 19th centuries
- Explain the development of transport industry during the Industrial Revolution
- Examine the life history of James Watt and his contribution in the development of steam engine

8.2 SIGMUND FREUD

Sigmund Freud was a late 19th and early 20th century physiologist, medical doctor and influential thinker. He was born on 6 May 1856 to Jewish parents in the Moravian town of Freiberg in the Austrian Empire. His family shifted to Vienna when Freud was four years old. He joined a school in Leopoldstadt where he excelled in Greek, Latin, history, math, and science. He became the Doctor of Medicine in 1881 from the University of Vienna. Freud began his medical carrier in 1882 at the Vienna General Hospital working with Joseph Breur. For three years he worked in different departments of the hospital. After completing his habilitation in 1885, he was appointed as docent in neuropathy. He resigned from the hospital in 1886 and opened his first private practice specializing in nervous disorders. In 1886, Freud married Martha Bernays and the couple had six children. The youngest of Freud's children, Anna Freud, became a prominent psychologist and ardent defender of her father's theories.

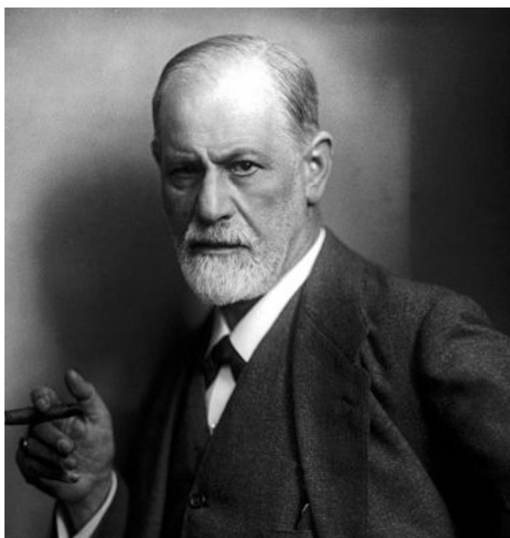


Fig 8.1 *Sigmund Freud*

Source:https://commons.wikimedia.org/wiki/File:Sigmund_Freud_LIFE.jpg

Shortly after getting married Freud entered into friendship with the Berlin based ENT specialist Wilhelm Fliess, whose role in the development of psychoanalysis caused widespread debate. Fifteen years of their friendship provided Freud an important partner for his most daring ideas. Freud's belief in

human bisexuality, his awareness of erogenous zones on the body, and perhaps even his assertion of sexuality to infants may well have been stimulated by their friendship.

The varying results of Freud's early clinical work ultimately led him to abandon hypnosis. He determined that hypnosis was an ineffective means to achieve the desired results and he started implementing talking therapy with his patients. This method came to be called as a 'talking cure' and the purpose was to encourage the patient to tap into the unconscious mind and release the repressed energy and emotions therein without inhibition. Freud discovered that patients' dreams could be effectively analysed to reveal the complex structuring of unconscious material and to demonstrate the psychic action of repression which, he had concluded, caused symptom formation. In 1896, he used the term psychoanalysis to refer to his new clinical procedure and its theories. The element of using talk therapy eventually became the foundation of psychoanalysis.

Relying on the philosophers such as Nietzsche, Dostoevsky, and Kant—Freud's theories continue to influence much of modern psychology. His ideas also resonated throughout philosophy, sociology and political science, with thinkers like Karl Marx drawing heavily upon the theory of Freud. His stress upon early life and the drive to pleasure were perhaps his most noteworthy contributions to psychology. Even contemporary psychologists who refute Freud's theories often took interest in patient's early life and the relationship between child and parent. Some of his most significant theories are explained below:

(i) Freud claimed that the mind consists of the conscious mind, which contains the thoughts and beliefs of which we are aware. However, the unconscious mind is a storehouse for suppressed memories and unexpressed desires, and problems with the unconscious mind can lead to problems with behaviour and emotional regulation.

(ii) On the basis of his theory of the unconscious mind, Freud developed the concepts of three complex behaviours: id, ego, and superego. Id is the primitive and intuitive part of the personality. It comprises sexual and aggressive drives and hidden memories. The ego is that part of the id which has been modified by the direct influence of the external world. The superego includes the values and morals of society which are learned from one's parents and others.

(iii) Freud gave the concept of psychosexual stages of development. It is the fundamental element in his sexual drive theory. According to Freud, sex drive is the most important force in man, including children as well as infants. He suggested psychosexual stages of development with regard to pleasurable sensation. These stages which include the oral, anal, phallic, latent and genital represent different stages of child development. Each stage is represented by the erogenous zone which is the source of libidinal drive

at that stage. Oedipal crisis is one of the most popular and debated sub-theories within the stages of psychosexual development. It is the attachment of the child with the parent of the opposite sex, accompanied by envy and aggression towards the parent of the same sex. It can be resolved by the identification with the parent of the same sex.

(iv) Freud proposed defence mechanisms which are tools of the unconscious mind that are intended to alter reality so as to avoid pain and suffering. For example, repression is the tendency to forget troubling events, while projection is the tendency to project one's own traits onto someone else. These defence mechanisms were further developed and codified by his daughter Anna Freud.

(v) Freud believed that dreams could be construed to collect important information about the personality and psychology of a person, and he believed that dreams frequently served as wish-fulfilment devices.

Freud developed and refined his theory and practice of psychoanalysis. His lectures and books brought him both ostracism and fame. He immigrated to England prior to the Second World War. He developed cancer in 1923 and passed away on 23 September 1939. His ideas are widely debated today, and his techniques and interpretations are commonly accepted as the foundation of modern psychoanalysis. He is regarded as the founding father of psychoanalysis, a method for treating mental illness and also a theory which explains human behaviour. He is one of the most famous figures in the history of psychology.

Check Your Progress

1. When and where did Sigmund Freud begin his medical career?
2. What was the basic objective of the 'talk therapy' devised by Sigmund Freud?

8.3 PROGRESS IN TECHNOLOGY

The production of fabrics, especially cotton, was fundamental to Britain's economic development between 1750 and 1850. The organization of cotton production shifted from a small-scale cottage industry, in which rural families performed spinning and weaving jobs in their homes, to a large, mechanized, factory-based industry. The boom in productivity began with a few technical devices, including the spinning jenny, spinning mule and power loom.

The Industrial Revolution drastically changed the means of transportation. Earlier transportation relied on animals and boats. Roads, canals, and railways were the three major components of transportation which improved during the Industrial Revolution.

8.3.1 Textile Industry

The Industrial Revolution took place chiefly from developments in the textile industry which was the major industry of those times. The textile industry was based on the development of cloth and clothing. Prior to the Industrial Revolution, the goods were produced on a very small scale. Historians called this method of production as the 'cottage industry'. In simple words, the cottage industry refers to a period of time in which goods for sale were produced on a very small scale, generally in a home. It was the cotton textile industry that provided its character to the Industrial Revolution in Britain. Cotton manufacture in Britain was transformed from those of a small-scale domestic industry spread over the towns and villages into those of a large-scale, concentrated, power-driven, mechanized, factory-organized and urban industry. It was undoubtedly; a dramatic transformation both to contemporaries and to the future, and it had great significance in the overall pattern of British industrialization.

Throughout the 18th century, inventors such as Richard Arkwright, Eli Whitney, James Hargreaves, Crompon, John Kay and Edmund Cartwright invented machines and techniques that helped improve production, especially in the context of the textile industry. For example, in 1733, John Kay developed Flying Shuttle which improved weaving efficiency and reduced labour needs because it could be operated with only a single operator. In 1764, James Hargreaves invented the Spinning Jenny which allowed a machine with many spindles of thread to be spun at one time. To add to this, Richard Arkwright developed the Water Frame in 1769. This machine allowed over one hundred spindles of thread to be spun at one time but was so large and required enormous energy that he built it next to rivers and creeks so as to use the force of the water to spin the machine. In 1785, Edmund Cartwright developed the Power Loom which allowed quicker production of cloth. Finally, in 1793, American inventor, Eli Whitney developed the Cotton Gin, which allowed for quicker production of cotton. Earlier, cotton had to be hand cleaned in order to remove fibres and seeds. Whitney's cotton gin sped up this process and allowed for much faster harvesting of the resource.

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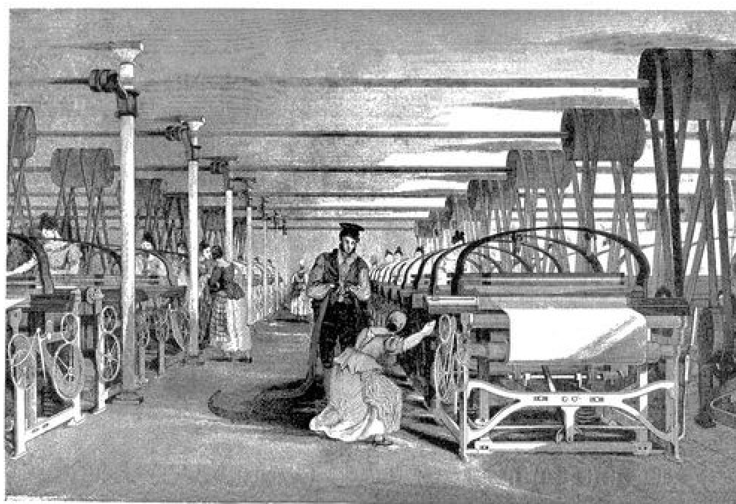


Fig 8.2 *Power Loom Weaving in 1835*

Source: https://commons.wikimedia.org/wiki/File:Powerloom_weaving_in_1835.jpg

But the importance of these machines in the history of technology should not be exaggerated. Undoubtedly, there were numerous interesting mechanical improvements, at least at the beginning of the transformation. The change of the spinning wheel into the spinning jenny, and the use of rollers and moving trolleys to mechanize spinning in the shape of the frame and the mule, respectively, commenced a radical rise in the productivity of the industry.

However, these were secondary innovations in the sense that there were precedents for them in the experiments of the previous generation; that in any case, the first British textile factory was the Derby Silk Mill built in 1719; and that the most far-reaching innovation in cotton manufacture was the introduction of steam power to drive carding machines, spinning machines, power looms and printing machines. But the cotton innovators should not be deprived of credit for their initiative and inventiveness in transforming the British cotton industry and making it the model for later developments in industrialization. The market for textile machinery and textile processing triggered the development of iron and chemical industries. All these industries necessitated an ever increasing supply of coal, which required new developments in mining and transport. Not only the cotton industry model was it copied, belatedly and slowly, by the woolen-cloth industry in Britain, but wherever other countries sought to industrialize they tried to acquire British cotton machinery and the know-how of British cotton industrialists and artisans. The British cotton industry gave a dynamic stimulus to other industries and processes which in turn led to its rapid rise.

The new mechanical industry developed around coal fields. However, it was the use of the steam engine for power in the textile industry that really created the industrial complex of the modem world. It revolutionized textile production, so much so, that production of goods increased almost five fold within 20 years.

8.3.2 Transport Industry

Industrial development was closely related to the improvement of transportation. Transport provided an example of a revolution within the Industrial Revolution, so completely were the modes transformed in the period between 1750 and 1900. As industrialization increased the need for transport and travel, the construction of toll roads and canals became a profitable business. There were three main types of transportation that got enhanced during the Industrial Revolution: waterways, roads and railroads. In the second half of the 18th century, there were improvements in roads and canals in Britain. Although of great economic significance, these were not of much importance in the history of technology, as good roads and canals had already existed in continental Europe. Britain added thousands of miles to its system of roads and canals during the 18th century and there was a network of hard-surfaced roads in France before the revolution. Napoleon improved the situation further by pushing highways far into Germany and Netherlands.

However, by the beginning of the 19th century, British engineers were beginning to innovate in both road- and canal-building techniques, with John Loudon McAdam's inexpensive and long-wearing road surface of compacted stones and Thomas Telford's well-engineered canals. Undoubtedly, the outstanding innovation in transport was the application of steam power, which occurred in three forms.

First was the evolution of the railroad system. It was the combination of the steam locomotive and a permanent travel way of metal rails. George Stephenson built the Stockton & Darlington Railway in 1821 using iron nails and steam power. However, the first time railway used a true steam locomotive running on rails was the Liverpool and Manchester Railway in 1830. This railway was designed by Stephenson and the locomotives were the work of Stephenson and his son Robert. The opening of the Liverpool and Manchester line may fairly be regarded as the inauguration of the railway era which continued until the First World War. There was such a boom in the railway construction that 'railway mania' was said to have swept the country. It was the time when railways were constructed across the globe, opening up vast areas to the markets of the industrial society. Locomotives increased rapidly in power and size, but the basic principles remained the same as those established by the Stephensons In the meantime, the construction of the permanent way experienced a corresponding improvement on that which had been common on the preceding tram roads.

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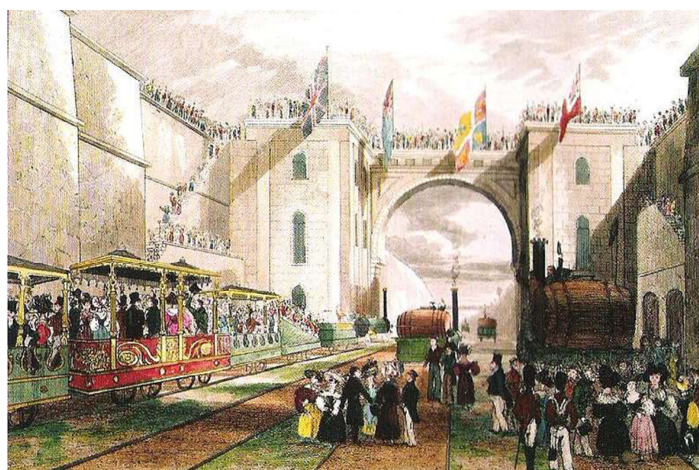


Fig 8.3 *The Opening of the Liverpool and Manchester Railway*

Source:https://commons.wikimedia.org/wiki/File:Opening_of_the_ Liverpool_and_ Manchester_Railway.jpg

The second form in which steam power was applied to transport was that of the road locomotive. It enjoyed a success equivalent to that of the railway engine, but its development was so limited by the unsuitability of most roads and by the jealousy of other road users that it achieved general utility only for heavy traction work and such duties as road rolling. The steam traction engine, which could be willingly improved from road transport to power farm machines, was nonetheless a distinguished product of 19th century steam technology.

The third form was substantially more important, since it transformed marine transport. The initial efforts to utilize a steam engine to power a boat were made in 1775 in France on the Seine River and a number of experimental steamships were built by William Symington in Britain at the turn of the 19th century. However, the first commercial success in steam propulsion for a ship was that of the American Robert Fulton. His paddle steamer the 'North River Steamboat,' generally called as the *Clermont* after its first overnight port, worked between New York and Albany in 1807. It was equipped with a Boulton and Watt engine of the modified beam or side-lever type, with two beams placed alongside the base of the engine in order to lower the centre of gravity. A similar engine was installed and put in service on the Clyde in 1812 in the Glasgow-built *Comet*, and was the first successful steamship in Europe. All the early steamships were driven by paddle, and all were small vessels which were suitable only for ferry and packet duties. In the 1830s Brunel started applying his innovative mind to the problems of steamship construction. He launched three great steamships and each marked a leap forward in technique—The *Great Western*, *Great Britain* and *Great Eastern*. By the end of the century, steamships were well on the way to displacing the sailing ship on all the main trade routes of the world.

Check Your Progress

3. Mention two significant developments which took place in the textile industry during the latter phase of the Industrial Revolution.
4. Name the three main types of transportation that got enhanced during the Industrial Revolution.

8.4 JAMES WATT-STEAM ENGINE

James Watt was an inventor, mechanical engineer and chemist who was born on 19 January 1736, at Greenock in Scotland. His father was a shipwright, ship owner and contractor while his mother came from a distinguished family and had a forceful character. In his early years, James Watt was educated at home by his mother and later he joined Greenock grammar school. He had lot of interest in tools, drawing and geometry. After completing his school education, James Watt worked in his father's workshops, demonstrating considerable skills in creating engineering models. Later, he got a job in Glasgow as a mathematical instrument maker.

In 1759 James formed a partnership with John Craig, an architect and businessman, to manufacture and sell a line of products including musical instruments and toys. He got married in 1764 and had five children. He lived in Regent Place, Birmingham from 1777 to 1790.

There is a popular story that Watt was inspired to invent steam engine when he witnessed that the steam of his tea pot was forcing the cover with a significant pressure. He got interested in utilizing the pressure of steam for producing continuous motion. He consulted Professor Black and ultimately built a steam engine. The iron and textile industries adopted Watt's Engine. Steam engines came running on rail roads due to the efforts of James Watt. His invention inspired many young minds including that of Stephenson (AD 1781-1848).

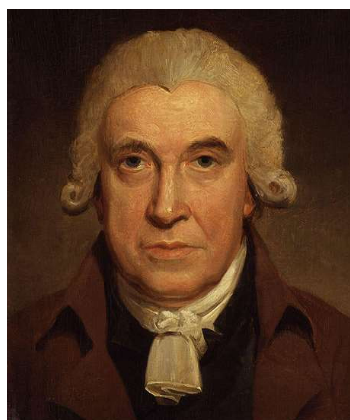


Fig 8.4 *James Watt*

Source: https://commons.wikimedia.org/wiki/File:James_Watt_by_Henry_Howard.jpg

NOTES

Apart from steam-engine, James Watt invented many other things such as a letter-copying press, musical organs, etc. He also designed apparatus for the manufacture of gases and for determining the specific gravities (S.G.) of liquids. He died on 25 August 1819 at Birmingham.

Steam engine

Steam engine is a machine which uses steam power to perform mechanical work through the agency of heat. In a steam engine, hot steam is generally supplied by a boiler which expands under pressure, and part of the heat energy is converted into work. Of all the inventions in the early years of industrialization, the steam engine was the most important. Until the advent of electricity, steam engine remained the principal source of power, and even in our atomic age its usefulness has not entirely ended. The development of the steam engine is closely associated with the two industries that ultimately proved basic to all modern economic progress—coal and iron. At the beginning of the 18th century, the smelting of iron was still done by charcoal. However, the depletion of Britain's wood supply and the discovery after 1700 of a process for smelting iron with coke, shifted the emphasis to coal. The mining of coal was made considerably easier by a primitive steam engine, developed by an Englishman, Thomas Newcomen in 1712. It was used to pump water from the coal mines.

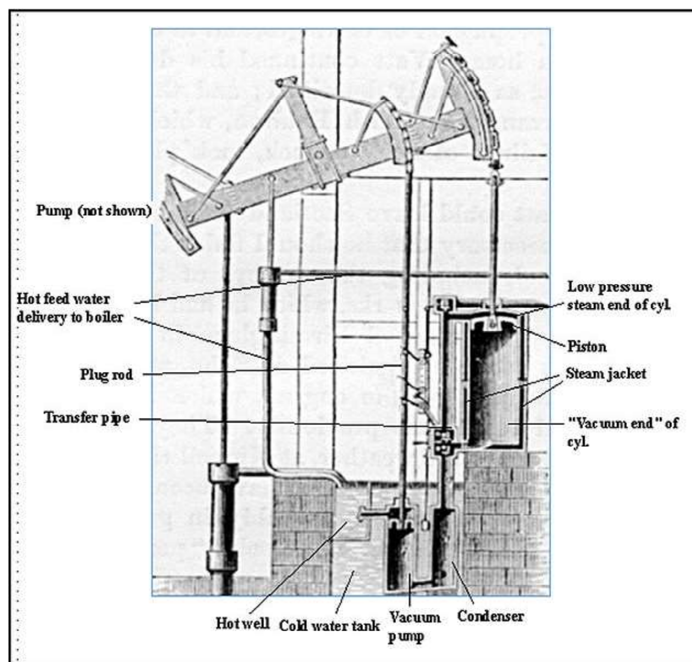


Fig 8.5 *Watt Steam Pumping Engine*

Source: https://commons.wikimedia.org/wiki/File:Watt_steam_pumping_engine.JPG

This engine was a long way from the kind of steam engine that could be used to run other machines. The credit for developing such an engine in 1765 goes to James Watt, who patented his first steam engine in 1769. Watt was perplexed by enormous amount of steam consumed by Newcomen's engine and realized that to overcome this inefficiency, he would have to do away with the constant cooling and reheating of the steam cylinder. He made considerable improvements in the Newcomen's engine. He first conceived the idea of a separate condenser, a chamber attached to the cylinder into which the steam could be admitted and condensed, without the necessity of cooling the cylinder itself. This allowed the steam cylinder to be maintained at a constant temperature and dramatically improved the functionality of Newcomen's engine. He devised a method by which the steam and not the atmospheric air could be used to move the piston. He adapted the piston to rotary motion enabling it to turn a wheel and driving machinery.

However, due to financial reasons and incapable workmen Watt was not immediately able to manufacture his new and improved engine. In 1776, he entered into a partnership with Matthew Boulton who provided him financial backing. The nucleus of a craft of skilled engineers was created, and the difficulties in the way of capable workmanship were reduced by the invention of Maudsley's slide-rest. Watt developed a new engine that rotated a shaft instead of providing the simple up-and-down motion of the pump, and he added many other improvements to produce a practical power plant.

Watt's improvements to the steam engine, coupled with Boulton's vision of a nation powered by steam, aided the rapid adoption of steam engines across the United Kingdom and, eventually, the United States. James Watt is called as the father of modern steam engine. By 1800, some three hundred steam engines were at work in mills, factories, breweries and in other manufacturing operations. The use of steam engines, of course, further increased the need for coal and iron. Improvements in iron production, on the other hand, in turn led to improvements in the making of steam engines. The interaction of one discovery with another continued to be a major characteristic of industrial development.

Check Your Progress

5. When did James Watt die?
6. Who is called as the father of modern steam engine?

8.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Freud began his medical carrier in 1882 at the Vienna General Hospital working with Joseph Breur.

2. The basic objective of the 'talk therapy' devised by Sigmund Freud was to encourage the patient to tap into the unconscious mind and release the repressed energy and emotions therein without inhibition.
3. Two significant developments which took place in the textile industry during the latter phase of the Industrial Revolution are the following:
   (i) In 1764, James Hargreaves invented the Spinning Jenny which allowed a machine with many spindles of thread to be spun at one time.
   (ii) Richard Arkwright developed the Water Frame in 1769. This machine allowed over one hundred spindles of thread to be spun at one time but was so large and required enormous energy that he built it next to rivers and creeks so as to use the force of the water to spin the machine.
4. The three main types of transportation that got enhanced during the Industrial Revolution were waterways, roads and railroads.
5. James Watt died on 25 August 1819 at Birmingham.
6. James Watt is known as the father of modern steam engine.

8.6 SUMMARY

- Sigmund Freud was a late 19th and early 20th century physiologist, medical doctor and influential thinker.
- In 1886, Freud married Martha Bernays and the couple had six children. The youngest of Freud's children, Anna Freud, became a prominent psychologist and ardent defender of her father's theories.
- The varying results of Freud's early clinical work ultimately led him to abandon hypnosis. He determined that hypnosis was an ineffective means to achieve the desired results and he started implementing talking therapy with his patients.
- Freud gave the concept of psychosexual stages of development. It is the fundamental element in his sexual drive theory.
- Freud proposed defence mechanisms which are tools of the unconscious mind that are intended to alter reality so as to avoid pain and suffering.
- Freud developed and refined his theory and practice of psychoanalysis. His lectures and books brought him both ostracism and fame.
- The production of fabrics, especially cotton, was fundamental to Britain's economic development between 1750 and 1850.

- The Industrial Revolution took place chiefly from developments in the textile industry which was the major industry of those times. The textile industry was based on the development of cloth and clothing.
- In 1764, James Hargreaves invented the Spinning Jenny which allowed a machine with many spindles of thread to be spun at one time.
- There were three main types of transportation that got enhanced during the Industrial Revolution: waterways, roads and railroads. In the second half of the 18th century, there were improvements in roads and canals in Britain.
- First was the evolution of the railroad system. It was the combination of the steam locomotive and a permanent travel way of metal rails. George Stephenson built the Stockton & Darlington Railway in 1821 using iron nails and steam power.
- James Watt was an inventor, mechanical engineer and chemist who was born on 19 January 1736, at Greenock in Scotland.
- There is a popular story that Watt was inspired to invent steam engine when he witnessed that the steam of his tea pot was forcing the cover with a significant pressure.
- Steam engine is a machine which uses steam power to perform mechanical work through the agency of heat. In a steam engine, hot steam is generally supplied by a boiler which expands under pressure, and part of the heat energy is converted into work.
- Watt's improvements to the steam engine, coupled with Boulton's vision of a nation powered by steam, aided the rapid adoption of steam engines across the United Kingdom and, eventually, the United States.

8.7 KEY WORDS

- **Cottage Industry:** It is an industry in which the manufacture of products is usually done at homes by people using their own tools and equipment.
- **Cotton Gin:** It is a device which separates the seeds from cotton fibre.
- **Erogenous Zones:** These are parts of the body that excite sexual feelings when touched or stimulated.
- **Spinning Jenny:** It is an engine that uses steam to produce power.
- **Steam Engine:** It is an engine that uses steam to produce power.
- **Textile:** A textile is a type of cloth or woven fabric.

NOTES

8.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Who was Sigmund Freud?
2. How did the Industrial Revolution lead to changes in transportation?
3. How did James Watt contribute to the Industrial Revolution?

Long-Answer Questions

1. Discuss the significant theories of Sigmund Freud.
2. Explain the concept of psychosexual stages of development given by Freud.
3. Describe the progress made in the field of textile industry during the Industrial Revolution.
4. Describe the stages which led to the development of the steam engine by James Watt.

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NOTES

UNIT 9 SCIENCE AND TECHNOLOGY IN THE 17TH AND 18TH CENTURIES-III

Structure

9.0 INTRODUCTION

Although chemicals were manufactured and used throughout history yet the beginning of the heavy chemical industry coincided with the beginning of the Industrial Revolution in general. The growth of textile industry in Britain brought about an upsurge of interest in the chemical industry. In the 19th century, there were two great innovations in the field of communication technology—Telegraph and Telephone. The world became closer by the spread of instantaneous communication. The first was the electric telegraph invented by British inventors, Sir William Cooke and Sir Charles Wheatstone in 1837 and the other was telephone invented by Alexander Graham Bell in 1876. It is believed that Thomas Alva Edison is more responsible than anyone else for creating the modern world as we know it today. With inventions like the phonograph, the electric light bulb, and a number of patents to his name this is possibly quite true.

9.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the growth of Modern Chemical Industry
- Explain the invention of Dynamite by Alfred Nobel
- Assess the two great innovations in communication technology—Telegraph and Telephone

9.2 MODERN CHEMICAL INDUSTRY

NOTES

The modern chemical industry virtually came into being with the objective of developing faster bleaching techniques for the British cotton industry.

In the middle of the 18th century, sulphuric acid was the first chemical to be produced in large amounts. John Roebuck invented the method of mass production of sulphuric acid in lead chambers. In 1749, Roebuck along with Samuel Garbett were the first to set-up a large scale factory in Prestonpans in 1749, which used leaden condensing chambers for the production of sulphuric acid. The acid was directly utilized in the bleaching process, but it was also used in the production of more effective chlorine bleaches, and in the manufacturing of bleaching powder. This product successfully met the necessities of the cotton textile industry. After that, the focus of chemical industry turned towards the needs of other industries, and particularly towards fulfilling the increasing demand for alkali in soap, glass, and a variety of other manufacturing processes. This resulted in the successful establishment of the Leblanc soda process which was patented by Nicolas Leblanc in France in 1791, for mass manufacture of sodium carbonate (soda). It was the key alkali process used in Britain until the end of the 19th century, although the Belgian Solvay process, which was significantly more economical, was substituting it elsewhere.

In the early 18th century, bleaching of cloth was done by treating it with sour milk or stale urine and exposing it to sunlight for a very long time, which resulted in retarded production. Sulphuric acid began to be used as a more efficient agent in addition to lime by the middle of the century, but it was the discovery of bleaching powder by Charles Tennant that encouraged the creation of the first great chemical industrial enterprise. It was manufactured by reacting chlorine with dry slaked lime and proved to be a cheap and successful product. He started a factory in St. Rollox, north of Glasgow and production increased considerably.

Since ancient times, soda ash was used in the production of textile, glass, soap and paper. In Western Europe, wood ashes had traditionally been the source of the potash. However, by the 18th century, as a result of deforestation, this source was becoming uneconomical and the French Academy of Sciences offered a handsome reward for a method to produce alkali from sea salt (sodium chloride). The Leblanc process was an early industrial process for the production of soda ash. It was patented in 1791 by Nicolas Leblanc. He was denied his prize money due to the French Revolution.

However, the Leblanc process became popular in Britain. William Losh built the first soda works in Britain in 1816 but it remained on a small-scale due to high tariff on salt production. When these tariffs were annulled, the British soda industry was able to expand rapidly. James Muspratt's chemical works in Liverpool and Charles Tennant's complex near Glasgow turned out to be the largest chemical production centres. In the late 19th century, the British soda production increased manifold.

As the Industrial Revolution progressed, these huge factories started manufacturing a wide range of chemicals. Initially, huge amount of alkaline waste was vented into the environment from the production of soda. It incited one of the first environmental legislations to be passed in 1863. It led to close inspection of factories and levied heavy fines on those producing beyond pollution limits. Soon various methods were devised to make useful byproducts from the alkali.

A Belgian industrial chemist Earnest Solvay developed the Solvay process in 1861. In 1864, Solvay along with his brother Alfred built a plant in Charleroi, a Belgian town and in 1874; they expanded into a larger plant in Nancy, France. This process proved more economical and less polluting than the Leblanc method, and it became popular. Ludwig Mond visited Solvay in 1874 to acquire the rights to use his process, and he and John Brunner formed the firm of Brunner, Mond & Co., and built a Solvay plant at Winnington, England. Mond contributed in making the Solvay process a commercial success. He made a number of modifications between 1873 and 1880 that removed byproducts that could impede or stop the mass production of sodium carbonate by this method.

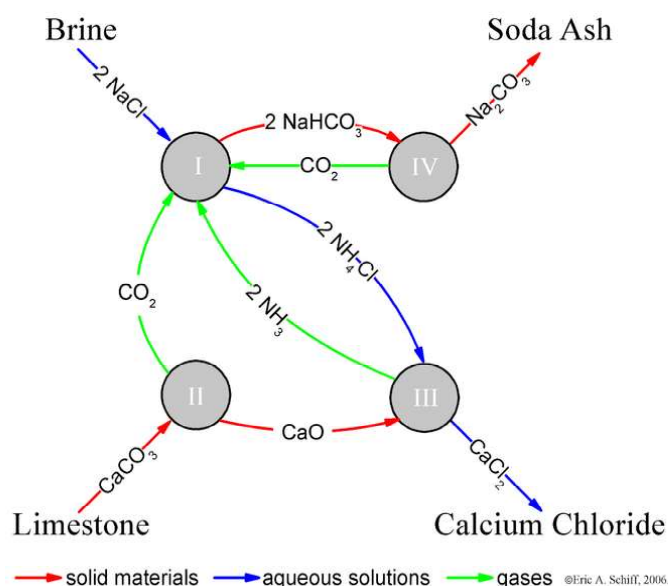


Fig 9.1 *Solvay Process*

Source:https://commons.wikimedia.org/wiki/File:Solvay_Process.PNG

In the late 19th century, there was substantial increase in both the quantity of production and the range of chemicals that were manufactured. Large chemical industries were established in Germany and later in the United States. Sir John Lawes pioneered the production of artificially manufactured fertilizer for agriculture at his purpose-built Rothamsted Research facility. He established large works near London for manufacturing superphosphate of lime. In the 1840s, Charles Goodyear patented the processes of vulcanization of rubber in the United States and Thomas Hancock in England. William Henry Perkin discovered the first

synthetic dye in London. He partly altered aniline into a crude mixture which, when extracted with alcohol, produced a substance with an intense purple colour. He also manufactured the first synthetic perfumes. However, the German firms rapidly started dominating the field of synthetic dyes. The three German chemical companies BASF, Bayer and Hoechst produced a plethora of different dyes, and by 1913, the German companies produced almost 90 per cent of the world supply of dyestuffs and sold about 80 per cent of their production abroad.

The history of petrochemical industry can be traced back to the oil works of James Young in Scotland and Abraham Pineo Gesner in Canada. Alexander Parkes, an English metallurgist invented the first plastic. In 1856, he patented Parkesine which was a celluloid based on nitrocellulose treated with different solvents. In 1885, William Lever and his brother James started the industrial production of soap from vegetable oils in Lancashire by using modern chemical process invented by William Hough Watson that used glycerin and vegetable oils. In the early decades of the 20th century, chemical firms consolidated into big companies; IG Farben in Germany, Rhône-Poulenc in France and Imperial Chemical Industries in Britain. Dupont turned out to be a major chemical company in the early 20th century in United States.

Check Your Progress

1. Who invented the method of mass production of sulphuric acid?
2. Who pioneered the production of artificially manufactured fertilizer for agriculture?
3. Who discovered the first synthetic dye?

9.3 DYNAMITE

Dynamite, a blasting explosive, was invented by Swedish chemist Alfred Nobel in the 1860s. Alfred's father, Immanuel Nobel, was an industrialist, engineer and inventor. He built bridges and buildings in Stockholm. It was his construction work which inspired Alfred to research new methods of blasting rock that were more effective than black powder. After suffering business losses in Sweden in 1838, Immanuel shifted to St. Petersburg, where Alfred and his brothers received education. Alfred was sent abroad for two years. In the United States, he met Swedish engineer John Ericsson and studied at Professor J.T Pelouze's lab at Paris in France. He also studied under Pelouze's pupil Ascanio Sobrero, an Italian chemist, who had first synthesized nitroglycer in in 1847 by mixing glycerol with nitric and sulphuric acids. Nitroglycerin does not burn off, it detonates. When there is breakage of molecular bonds between the liquid's carbon, nitrogen, hydrogen and oxygen, the molecules rearrange into gasses like dinitrogen and carbon monoxide. This process triggers a chain reaction that charges through the fuel, sending out a white-hot, supersonic wave with an explosive energy much

greater than that of the black powder. Any bump or jolt can trigger the reaction, making nitroglycerin highly unstable. Hence, Sobrero believed that his discovery had no practical utility.

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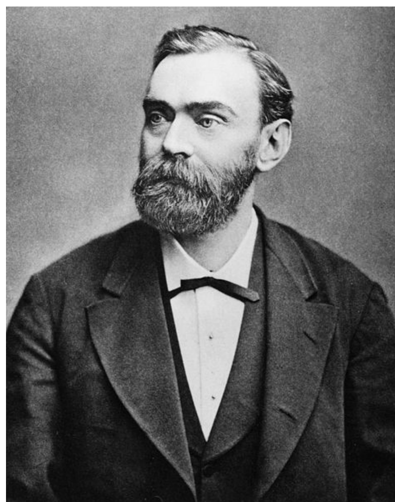


Fig 9.2 *Alfred Nobel*

Source: https://commons.wikimedia.org/wiki/File:AlfredNobel2.jpg

When Alfred Nobel was in France, he first came to know about nitroglycerin. Although nitroglycerin was a very powerful explosive yet it was very unstable and could not be handled with much safety. So Alfred established a small nitroglycerin factory to supply his experiments and started working. HeAlfred filed a number of patents in 1857, mostly associated with air pressure, gas and fluid gauges, but continued to be fascinated with nitroglycerin's potential as an explosive. He worked hard to improve nitroglycerin as an explosive that could be used in blasting rock and in mining. He experimented with different combinations of nitroglycerin and black powder. Eventually, Alfred came up with a solution to safely detonate nitroglycerin by inventing a small wooden detonator, or blasting cap, that allowed a controlled explosion set off from a distance using a fuse. This detonator marked the beginning of Alfred Nobel's reputation as an inventor in addition to the fortune he was to acquire as a developer of explosives. In 1865 Nobel invented an improved detonator called a blasting cap. Alfred performed his first successful detonation of pure nitroglycerin in 1863, using a blasting cap made of a copper percussion cap and mercury fulminate. In 1864, Alfred Nobel filed patents for both the blasting cap and his method of synthesizing nitroglycerin, by using glycerine, sulphuric acid and nitric acid. The invention of blasting cap marked the beginning of the modern use of high explosives. On 3 September 1864 while experimenting with nitroglycerin, his brother Emil and several other people were killed in an explosion at the factory at Immanuel Nobel's estate at Heleneborg. Undaunted by this tragic accident, Alfred laid the foundation of the company *Nitroglycerin Aktiebolaget* (aven Nitroglycerin AB) in Vinterviken. He moved to Germany, where he founded another company, Dynamit Nobel.

As a commercial explosive, however, nitroglycerin was still useless due to its volatility despite the invention of the blasting cap. It remained difficult to transport and very dangerous to handle. In order to overcome this shortcoming, Alfred sought to mix it with another substance that would render it safe for transport and handling and still would not diminish its effectiveness as an explosive. He attempted several combinations of cement, coal, and sawdust, but could not succeed. Finally, he discovered that nitroglycerin was absorbed to dryness by *kieselguhr*, a porous siliceous earth, and the mixture so prepared was much safer to use and easier to handle. Thus, Alfred successfully stabilized nitroglycerin into a portable explosive.

Alfred Nobel obtained patents for his invention of Dynamite in England on 7 May 1867 and in Sweden on 19 October 1867. After this, the use dynamite rapidly gained popularity as a safe alternative to black powder and nitroglycerin. Nobel firmly controlled the patents and unlicensed a number of duplicating companies which were quickly shut down. However, few American businessmen got around the patent by using different absorbents. Alfred Nobel originally sold dynamite as Nobel's Blasting Powder but decided to change the name to Dynamite, from the Greek word *dynamis* meaning 'power'. The invention of Dynamite established Alfred Nobel's popularity all over the world and it came to be widely used in blasting tunnels, building roads and railways and cutting canals.

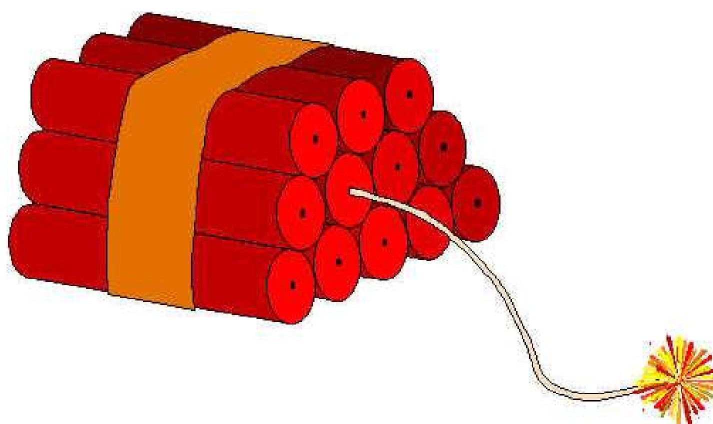


Fig 9.3 *Dynamite*

Source: https://commons.wikimedia.org/wiki/File:Dynamite_clipart.jpg

In the late 19th century, Alfred Nobel built a network of factories all over Europe for the manufacture of dynamite. He continued his research and in 1875, he invented a more powerful form of dynamite known as blasting gelatin. He also discovered that by mixing a solution of nitroglycerin with nitrocellulose, a tough plastic material with high water resistance and greater blasting power is formed. In 1887, he introduced ballistite which is a smokeless propellant prepared from two explosives nitrocellulose and nitroglycerin.

Alfred Nobel died in 1896 in San Remo, Italy. In his will, he left the bulk of his assets to a trust to establish a series of prizes which came to be known as 'Nobel Prizes'. These are widely regarded as the most prestigious awards in the

world given for intellectual achievement. They are awarded in the field of Physics, Chemistry, Physiology or Medicine, Literature, Peace and Economics. Except for the Peace Prize, these are presented in Stockholm, Sweden, on 10th December, which happens to be the death anniversary of Alfred Nobel.

Check Your Progress

4. In which year was the blasting cap invented by Alfred Nobel?
5. What was the original name of dynamite under which it was sold by Alfred Nobel?

9.4 TELEGRAPH

The word telegraph is derived from the Greek words *tele*, which means 'distant', and *graphein*, meaning 'to write'. The device or system that allows the transmission of information by coded signal over distance is called a telegraph. Many telegraphic systems have been used over the centuries, but the term is generally understood to refer to the electric telegraph, which was developed in the mid-19th century and for more than a century was the principal means of transmitting printed information through wire or radio wave.

Telegraph came into use toward the end of the 18th century in France to describe an optical semaphore system. However, various kinds of telegraphic communication have been employed before recorded history. The earliest methods of communication at a distance made use of such media like fire, drums, smoke and reflected rays of the Sun. Visual signals given by torches and flags were used for short-range communication and continued to be used even in the 20th century, when navies of the world widely used the two-flag semaphore system.

Prior to the development of the electric telegraph, visual systems were utilized to deliver messages over distances through variable displays. The semaphore developed in France in 1791 by the Chappe brothers—Claude and Ignace, was one of the most successful of the visual telegraphs. In 1795, George Murray of England developed another widely used visual telegraph. However, in the middle of the 19th century visual telegraphs were completely replaced by the electric telegraph.

The electric telegraph is the result of scientific evolution that had been taking place in the field of electricity since the 18th century. An electric telegraph is a point-to-point text messaging system. The invention of Voltaic Cell in 1800 by Alessandro Volta of Italy was one of the significant developments of the latter phase of the Industrial Revolution. As a result, it became possible to power electric devices in a more effective manner using comparatively low voltage and high currents. Earlier methods of producing electricity involved frictional generation of static electricity, which led to high voltages and low currents. A number of

devices incorporating high-voltage static electricity and various detectors like the pith balls and sparks were suggested for use in telegraphic systems. However, all proved to be unsuccessful because of the severe losses in the transmission wires, especially in bad weather, which restricted consistent operation to relatively short distances. Use of the battery in telegraphy was caused by a number of developments in the new science of electromagnetism. In 1820, Hans Christian Ørsted of Denmark discovered that an electric current produces a magnetic field that could deflect a magnetic needle. In the same year, Johann Schweigger invented the galvanometer. Also that year, Ampere suggested that telegraphy could be accomplished by placing small magnets below the ends of a set of wires, one pair of wires for each letter of the alphabet. In 1825, William Sturgeon invented electromagnet, and in 1831 Michael Faraday of Britain and Joseph Henry of the United States refined the science of electromagnetism adequately to make it possible to design practical electromagnetic devices. In 1837, the British inventors William Fothergill Cooke and Charles Wheatstone co-developed a patent on a telegraph system which used six wires and actuated five needle pointers attached to five galvanoscopes at the receiver. If currents were transmitted through the proper wires, the needles could be made to indicate particular letters and numbers on their mounting plate.

In 1832 Samuel Morse, became interested in the possibility of electric telegraphy. He developed a code (bearing his name) and devised a system of dots and dashes in 1835 to represent letters and numbers. In 1837 he patented a recording electric telegraph. Morse's original transmitter included a device known as portarule, which used a molded type with in-built dots and dashes. The type could be moved by means of a mechanism in such a way that the dots and dashes would make and break the contact between the battery and the wire to the receiver. The receiver imprinted the dots and dashes on an unwinding strip of paper that passed under a stylus. The stylus was activated by an electromagnet turned on and off by the signals from the transmitter.

Morse's assistant Alfred Vail designed an instrument known as register for recording the received messages. The first demonstration of Morse's system was conducted for his friends in 1837 at his workplace. In 1843 Morse sought financial aid from the US government to build a 60 km long demonstration telegraph system between Washington, D.C., and Baltimore. Wires were attached by glass insulators to poles besides a railroad. The system was finalized and initiated for public use on 24 May 1844 with transmission of the message, '*What hath God wrought!*' By 1866, a telegraph line had been laid across the Atlantic Ocean from the US to Europe. This initiated the telegraph era in the United States, which was to last more than a century. By the beginning of the 21st century, the use of telegraph was not widespread. It came to be substituted by the telephone, fax machine and Internet. However, it laid the foundations for the communication revolution that led to those later innovations.

NOTES

Check Your Progress

6. Who invented the Voltaic Cell?
7. When and by whom was electric telegraphy invented?

9.5 TELEPHONE

The term telephone is derived from the Greek word *tele* which means 'far' and *phone* meaning 'voice', together meaning 'distant voice'. A number of inventors pioneered experimental work on transmission of voice over a wire and improved on each other's ideas and innovations. Charles Bourseul, Antonio Meucci, Johann Philipp Reis, Alexander Graham Bell, and Elisha Gray and others have been credited with the invention of the telephone. However, the topic of inventor of telephone is a debatable one.

During the 1870s, Alexander Graham Bell and Elisha Gray, the two renowned inventors independently made devices that were able to transmit sound along the electric wires. Both devices were registered at the patent office on the same date. A legal battle ensued over the issue in which Bell won the case. Thus, Alexander Graham Bell was the first to be awarded a patent for telephone by the United States Patent and Trademark Office (USPTO) on 7 March 1876.

Three decades before Bell started experimenting; the telegraph had been a very successful communication system. However, the main problem with the telegraph was that it used Morse code, and was confined to sending and receiving only one message at a time. Graham Bell had good knowledge about the nature of sound and music which enabled him to perceive the idea of simultaneously transmitting multiple messages along the same wire. Although his idea was not new as multiple telegraph had been envisioned earlier. Bell designed a device called 'Harmonic Telegraph' that combined the aspects of the telegraph and record player to permit people to speak to each other from a distance. It was based on the principle that musical notes could be transmitted down the same wire at one time, if those notes had different pitch. While working on his harmonic telegraph, Bell heard the sound over the wire. Finally, on 10 March 1876, he realized the success of his new device. The potentials of being able to talk down an electrical wire far outweighed those of a modified telegraph system, which was based on just dots and dashes. Bell developed a prototype in which he sought the help of Thomas A. Watson, a Boston machine shop employee. In this first telephone, sound waves caused an electric current to differ in intensity and frequency, causing a thin, soft iron plate–called the diaphragm–to vibrate. These vibrations were magnetically transmitted to another wire connected to a diaphragm in another, distant instrument. When that diaphragm vibrated, the original sound would be replicated in the ear of the receiving instrument. While attempting to perfect this technology, Bell was backed by a group of investors.

Shortly after Graham Bell's patent application in 1876, Hungarian engineer Tivadar Puskas proposed the telephone switch, which allowed for the formation of telephone exchanges, and ultimately networks. In August 1876, Bell conducted a demonstration of his telephone by using two telegraph offices that were five miles apart. Using only the existing telegraph lines, he was able to conduct the world's first phone call in front of an audience of stunned spectators. He made first ever telephonic call to his assistant Watson, allegedly uttering the now-famous phrase, 'Mr. Watson, come here. I want you'. Bell and his partners offered to sell the patent for the telephone to Western Union, but it rejected the offer as it considered telephone as worthless. That inspired Bell and his partners to keep the telephone patent for themselves.

The Bell Telephone Company, which nowadays is known as AT&T, was established in 1877. In 1915, Bell made the first transcontinental telephone call to Watson from New York to San Francisco.

Check Your Progress

8. In which year was the Bell Telephone Company established?
9. Name the scientist who received the patent for telephone by the United States Patent and Trademark Office (USPTO) in 1876.

9.6 THOMAS ALVA EDISON-ELECTRIC LAMP

Thomas Alva Edison was an American inventor who was born on 11 February 1847, at Milan, Ohio to middle class parents, Samuel and Nancy Edison. He was youngest of the seven children. He was an extremely inquisitive boy. One spring evening, when he was five years old, his parents found him in a neighbour's born squatting patiently on a nest of duck eggs. He had been there for at least ten hours and was blue with cold. He was trying to see whether he could hatch the eggs.

When Thomas Edison was seven years old, his parents moved to Port Huron, Michigan where his father got a job. Thomas Edison had poor health in his early years which affected his studies at the school. His schoolmaster claimed that he was a retarded child. So his mother took him off school after a few months of formal education. Thomas, however, got an unusual form of education from his mother who used to be a school teacher. Before he was ten, he had read Parke's School of Natural Philosophy, Gibbon's Decline and Fall of Roman Empire, The Dictionary of Science and Sear's The Wonders of the World. Such reading stimulated his in- born quality of experimentation. Gradually, his farm-house cellar became a laboratory. He used to buy new science books as soon as they appeared.

At the age of 12, Thomas Edison decided to head for financial independence. He began his career in Grand Trunk Railways by selling candy, newspapers and vegetables on the trains plying between Port Huron and Detroit. In 1862, he was

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circulating 1000 copies of the daily published by the Detroit Free Press. Soon he bought a second-hand printing press. He set it up in a baggage car, and began turning out a tabloid-size paper called 'The Weekly Herald'. Besides the hand-press, young Edison had also established a chemical laboratory in which he conducted experiments outlined in his scientific readings. One afternoon, a highly combustible material broke on the floor of the baggage car, igniting newspapers and other inflammable material. After the fire was brought under control, Edison and his paraphernalia were thrown off the train. This ended his career in G.T. Railways.

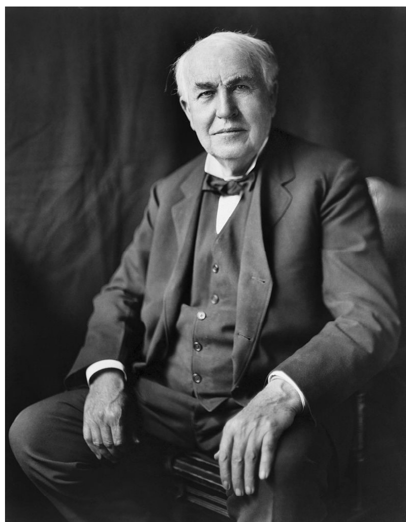


Fig 9.4 *Thomas Alva Edison*

Source:https://commons.wikimedia.org/wiki/Category:Thomas_Edison#/media/File:Thomas_Edison2.jpg

On one occasion, Thomas Edison saved the life of a three-year old boy on the rail tracks. The child's father, a telegrapher offered to teach him telegraphy. This was the beginning of his new career. Edison's interest and labour led him to become the best and fastest telegrapher in the United States. He started developing a multiplex telegraphic system, which could send two messages simultaneously. He spent all his savings on such experiments. His first patent was for an electrical vote recorder.

In 1869, Edison moved to New York City to find employment. While he was in a broker's office waiting to be interviewed, the master transmitter creaked to a halt. This master transmitter was sending fluctuating gold prices to the Gold Exchange and 300 brokerage houses. The operators, unable to find the trouble, were panic-struck. Edison tried to locate the defect and told the manager, 'The contact spring is broken. It has fallen between the gears.' Edison was asked to help the operators. He handled the trouble successfully within two hours. He was hired on the spot as a supervisor on a handsome salary. On Christmas Day of 1871, Edison married a charming lady Mary Stilwell.

In 1876, Edison opened his first industrial research laboratory, in Menlo Park in New Jersey. This was the time when Edison's productivity was at its

height. Western Union pressed Edison to improve the telephone, which Alexander Graham Bell had just patented. Edison invented the carbon granule microphone which produced higher output than the previous microphones. He also invented the phonograph. The imagination of people everywhere was captured by this machine which could actually store and reproduce the human voice. The name of Thomas Edison became better known than of any other living man. At this time, he was just 31 years of age. With 157 patents already to his credit and 78 pending in the Washington Patent Office, Edison followed a fantastic, steady work pattern. Edison was conferred honorary doctorate from Princeton University in 1878.

In 1884, Edison's wife died suddenly of typhoid fever. In 1886 he married Mina Miller, Happiness returned to his life. Edison worked on cameras for many years. In 1889, he actually showed a talking picture in his laboratory, synchronizing the film with a phonograph. Edison developed the first fluorescent electric lamp.

In 1915, Edison got a D.Sc. from Princeton University. In 1917, when America entered the First World War, Edison was appointed president of the Naval Consulting Board. He developed an apparatus to detect torpedoes, search-lights for submarines, turbine-powered projectiles and submarine stabilizers. He won the distinguished Service Medal.

At the age of 75, Edison cut his working hours down to 16 hours a day. At the age of 80 he brought out his first long playing phonograph record. During his lifetime, Edison was granted the surprising total of 1097 patents by the U.S. Patent Office.

Interviews with Edison were interesting. When asked about the secret of his success, he answered that 'genius is 2 per cent inspiration and 98 per cent perspiration'. Feature writers sought Edison's views on God and religion. Edison told them, 'I cannot doubt the existence of a Supreme Intelligence. The existence of a God can, to my mind, almost be proved from Chemistry'.

Edison died on 18 October 1931. Even three days before his death Edison was making plans for his experiments. On the night of his funeral, in response to U.S President Hoover's proclamation, lights all over America were turned off for one minute as a tribute to the man who had lighted those 52 years of that country and the world. It was just a coincidence that the date was the anniversary of the lighting of his first successful lamp in Menlo Park.

Electric Lamp

Edison directed his attention for getting light from electricity. Electric lighting was the latest sensation of the time. He started his work on incandescent light. He began as usual, by making an exhaustive review of what others had already done. Humphry Davy, James Bowman Lindsay, Moses G. Farmer Edison and others had earlier developed incandescent electric lamps. Incandescent lamps make light by using electricity to heat a thin strip of material (called a filament) until it gets hot enough to glow. Edison made a complete prototype of the electric lighting industry and established it as a practical public utility. He found that a British Patent (1841) had been granted on a lamp having two platinous coils with

powdered charcoal bridging the gap between them. Edison was looking for a wire that could be heated to incandescence by an electric current. After conducting experiments for one year at considerable expenditure, he found that platinum would not work. He produced a light bulb with carbonized filament of uncoated cotton thread that could last for 14.5 hours. He observed that heating (by passing electricity) the filament in vacuum gave an amazingly brighter light. On 21 October 1879, Edison set up a bulb with a scorched thread and it burned continuously for 40 hours. In 1880, the main street of Menlo Park was illuminated on New Year eve by electricity in a public demonstration. On 27 January 1880, Thomas Alva Edison received US Patent No. 223,898, which was simply titled 'Electric Lamp'. Edison found that carbonized bamboo filament was superior to the filament of carbonized cardboard. It increased the life of the lamp to 170 hours. While Edison was working on the whole lighting system, other inventors continue to make small advances, improving the filament manufacturing process and the efficiency of the bulb. The carbonized bamboo filament was replaced first by squirted cellulose, and then by tungsten, which is in vogue today. These new tungsten filament bulbs lasted longer and had a brighter light in comparison with the carbon filament bulbs.

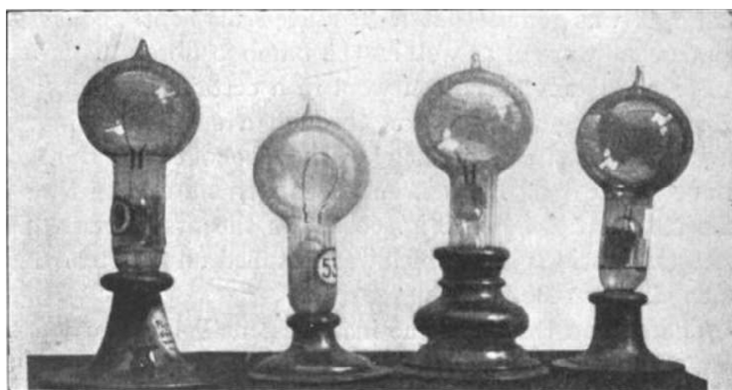


Fig 9.5 *Early Edison Light Bulbs*

Source: https://commons.wikimedia.org/wiki/Incandescent_light_bulb#/media/File:Edison_incandescent_lights.jpg

Edison not only generated electricity and devised electric bulbs but also made all arrangements at his personal cost for the domestic use of light generated from electricity. He completed his plans of putting wires underground in insulated conduits. On 4 September 1882, he switched on the new lighting system. The windows of the downtown district suddenly sprang to life. This scene created a profound impression. Many rightly called him 'The Wizard of Menlo Park'.

Check Your Progress

10. When and where did Edison open his first industrial research laboratory?
11. Name the scientist and inventor who was given the title of the 'The Wizard of Menlo Park'?

9.7 ANSWERS TO CHECK YOUR PROGRESS

1. John Roebuck invented the method of mass production of sulphuric acid in lead chambers.
2. Sir John Lawes pioneered the production of artificially manufactured fertilizer for agriculture at his purpose-built Rothamsted Research facility.
3. William Henry Perkin discovered the first synthetic dye in London.
4. The blasting cap was invented by Alfred Nobel in the year 1865.
5. Alfred Nobel originally sold dynamite as Nobel's Blasting Powder.
6. The Voltaic Cell was invented in 1800 by Alessandro Volta of Italy.
7. In 1832 Samuel Morse invented electric telegraphy.
8. The Bell Telephone Company, which nowadays is known as AT&T, was established in 1877.
9. Alexander Graham Bell was the first scientist who received the patent for telephone by the United States Patent and Trademark Office (USPTO) in 1876.
10. In 1876, Edison opened his first industrial research laboratory, in Menlo Park in New Jersey.
11. Thomas Alva Edison was given the title of the 'The Wizard of Menlo Park'.

9.8 SUMMARY

- Although chemicals were manufactured and used throughout history, the origin of the heavy chemical industry coincided with the beginning of the Industrial Revolution in general. The growth of textile industry in Britain brought about an upsurge of interest in the chemical industry.
- In the middle of the 18th century, sulphuric acid was the first chemical to be produced in large amounts. John Roebuck invented the method of mass production of sulphuric acid in lead chambers.
- Sulphuric acid was directly utilized in the leaching process, but it was also used in the production of more effective chlorine bleaches, and in the manufacturing of bleaching powder.
- It was the discovery of bleaching powder by Charles Tennant that encouraged the creation of the first great chemical industrial enterprise.
- In Western Europe, wood ashes had traditionally been the source of the potash. The Leblanc process was an early industrial process for the production of soda ash. It was patented in 1791 by Nicolas Leblanc.
- A Belgian industrial chemist Earnest Solvay developed the Solvay process in 1861. It is the major industrial process for the production of sodium carbonate.

- In the late 19th century, there was substantial increase in both the quantity of production and the range of chemicals that were manufactured. Rubber, dye, soap, vegetable oil etc., were manufactured.
- Dynamite, a blasting explosive, was invented by Swedish chemist Alfred Nobel in the 1860s. It was the construction work of his father that inspired Alfred to research new methods of blasting rock that were more effective than black powder.
- Alfred worked hard to improve nitroglycerin as an explosive that could be used in blasting rock and in mining. He successfully stabilized the nitroglycerin into a portable explosive.
- The device or system that allows the transmission of information through coded signal over distance is called a telegraph. Samuel Morse developed a code and devised a system of dots and dashes in 1835 to represent letters and numbers. In 1837, he patented a recording electric telegraph.
- The term telephone is derived from the Greek word *tele* which means 'far' and *phone* meaning 'voice', together meaning 'distant voice'. Charles Bourseul, Antonio Meucci, Johann Philipp Reis, Alexander Graham Bell, and Elisha Gray and others have been credited with the invention of the telephone.
- Alexander Graham Bell was the first to be awarded a patent for telephone in 1876. The Bell Telephone Company, which nowadays is known as AT&T, was created in 1877.
- Thomas Alva Edison was an American inventor who is credited with the invention of electric lamp. On 27 January 1880, he received patent for this invention. He also made contributions in the field of phonograph, the motion picture camera, as well as improving the telegraph and telephone.

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9.9 KEY WORDS

- **Detonator:** It is a small amount of explosive or a piece of electrical or electronic equipment which is used to explode a bomb or other explosive device.
- **Galvanometer:** It is a device used for detecting the presence of small current and voltage or for measuring their magnitude.
- **Paraphernalia:** It generally refers to a group of apparatus, equipment, or furnishing used for a particular activity.
- **Patent:** It is a form of intellectual property that gives its owner the legal right to exclude others from making, using, or selling an invention for a specified period in exchange for publishing an enabling public disclosure of the invention.

- **Phonograph:** It is an instrument for reproducing sounds through the vibration of a stylus or needle following a spiral groove on a revolving disc or cylinder
- **Vulcanization:** It is a chemical treatment process which involves the application of chemicals like sulphur to improve the physical properties of rubber.

9.10 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Briefly mention about the significant invention of dynamite by Alfred Nobel.
2. How was electric bulb invented?
3. Prepare an account of the life history of Thomas Alva Edison. How did he change the world?

Long-Answer Questions

1. Describe the evolution and development of modern chemical industry.
2. Discuss the development of electric telegraph system.
3. Explain the origin and development of telephone by Alexander Graham Bell.

9.11 FURTHER READINGS

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BLOCK - IV
SCIENCE AND TECHNOLOGY IN THE 19TH AND 20TH CENTURIES

NOTES

UNIT 10 SCIENCE AND TECHNOLOGY IN THE 20TH CENTURY I

Structure

10.0 INTRODUCTION

There were dramatic advancements in the field of science in the late 19th and 20th century. In fact, the 19th century has sometimes been called as the Age of Science. By the end of the 19th century, there was a great optimism about the power and value of science and technology. New and radical developments had taken place in chemistry and physics and they developed considerably in both theory and practice. New and radical developments also took place in the field of physical, life science and human sciences. The discovery of a new and mysterious form of radiation in the late 19th century revolutionized medical imaging. The discovery of radium and polonium revolutionized chemistry and signified a new epoch. The development of post-Newtonian theories in physics, like the special relativity, general relativity and quantum mechanics led to the development of nuclear weapons. New models of the atomic structure led to developments in theories of chemistry.

10.1 OBJECTIVES

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After going through this unit, you will be able to:

- Discuss the contribution of Albert Einstein in the development of modern physics
- Explain the discovery of X-rays by William Roentgen
- Analyse the account of the contribution of Marie Curie in science
- Discuss the contribution of Ernest Rutherford in the atomic theory
- Assess the invention of atomic bomb

10.2 ALBERT EINSTEIN

Albert Einstein was born in the city of Ulm, Wurttemberg, Germany on 14 March 1879 in a Jewish family. His father, Hermann Einstein was a salesman and his mother Pauline Koch was a housewife. He received his early education in a Catholic Elementary School in Munich. In school, he was not an exceptionally intelligent student. Except for mathematics, he was weak in almost every subject. His father left Munich for some business reasons and settled in Milan. Einstein stayed at school in Munich to get his diploma but after six months he gave up the struggle against the unbearable educational system and joined his parents at Milan.

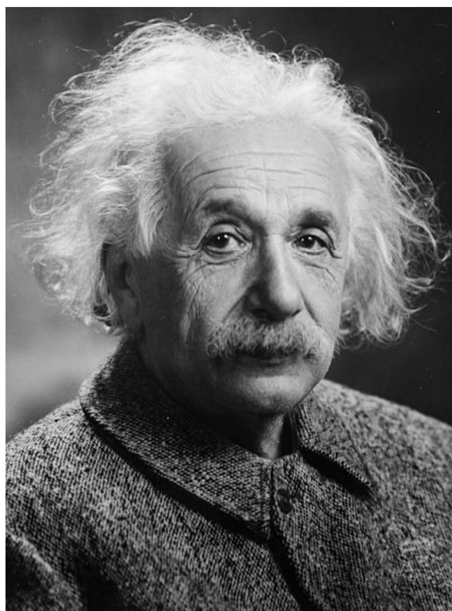


Fig 10.1 *Albert Einstein*

Source: *https://commons.wikimedia.org/wiki/File:Albert_Einstein_Head.jpg*

Einstein decided to study physics and went to Zurich to get enrolled in the Swiss Federal Polytechnic School. However, he failed to qualify the entrance examination and so was compelled to go back to school at Munich to complete his diploma. Then he got admission in the Federal Polytechnic, Zurich. He was poor and in spite of financial help from his relatives, often went hungry. That worried him less than the examinations. He said, 'constraint was so terrifying that after I had passed the final examination, I found myself unable to think on any scientific problem for almost a year'. After completing his studies at the age of 21, he got a job of technical assistant in the Swiss Federal Patent Office, Berne. In 1901, he married a 20 year old Serbian girl, Mileva Maric.

Einstein published groundbreaking papers between 1900 and 1909 which revolutionized the scientific outlook of the world. The papers dealt with subjects like the Special Theory of Relativity, Inertia of Energy, the Theory of Brownian Movement, the Quantum Law of Emission and the Absorption Theory of Light, the Theory of Specific Heat of Solid Bodies and the Fundamental idea of the General Theory of Relativity. In 1905, he published the longest of all the papers after a tremendous effort. His health deteriorated after this publication and he was not able to think on any scientific problem for a fortnight. The paper was titled *On the Electrodynamics of Bodies in Motion*. It was, in fact, a statement of the Special Theory of Relativity. In 1905, Einstein got a Ph.D. from Zurich University. Einstein believed that there is nothing in the universe which could be viewed as at 'absolute rest' or at 'absolute motion'. His theory is called as the theory of Relativity.

10.2.1 The Special Theory of Relativity

It is based on the following ideas:

(i) The speed of light always has the same value.

(ii) The laws of nature are the same for all bodies in uniform motions.

It states that:

(i) It is impossible to find out if two events happened at the same time.

(ii) All motion is relative.

(iii) An object in motion gets shorter in the direction of the motion, if it travels at 161,000 miles per second; its length in the direction of travel will be 50 per cent shorter.

(iv) Clocks in motion slow down.

(v) An object in motion has its mass increased because of the motion.

It led to:

$E = mc^2$ which implies 'energy equals mass times the speed of light squared.' i.e., the energy of a body is equal to the mass of the body multiplied by the square of the speed of light. This is the most famous equation in science. The equation infers that matter can be changed into energy and energy into matter. Relativistic

mechanics represents a valid system of natural laws linking the uniform motion of a body with the electromagnetic phenomena. Newtonian mechanics now merely forms its special case.

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In 1909, Albert Einstein joined as a Professor at the University of Zurich. There he worked from 1909 to 1911, after which he became a full-time Professor at the German Charles-Ferdinand University in Prague. He succeeded Professor Nant Hoff at Berlin in 1915. Here, he got good opportunity for research and devoted himself to it. Einstein completed his work on the General Theory of Relativity. There was not much hope for experimental proof and many thought that the generalization was mindboggling and doubtful. Later, the high speed of particles used in nuclear bombardment has brought relativistic velocities into the experimental range. An opportunity to test Einstein's hypothesis arose on 29 March 1919, at the time of a solar eclipse. Einstein's theory was justified. He modified the equations for natural laws so that they would apply to any part of space. The Special Theory covers only uniform motion, whereas the General Theory also covers accelerated and rational motion. His extension of relativistic ideas of accelerated motion provided a new description of gravitation. Newton's classical theory became a special case of Einstein's new theory of gravitation.

Einstein's reputation grew worldwide. He served as the Director of Kaiser Wilhelm Institute of Physics from 1914 to 1933. He remained a visiting Professor in European countries till 1933. In 1921, Einstein got the Nobel Prize in Physics for suggesting applications of the Quantum mechanics. He was selected as a foreign member of the Royal Society. In 1925, he was awarded the Copley Medal of the Royal Society.

In 1930, Einstein visited California to give lectures at the California Institute of Technology. At that time, Hitler had come to power in Germany. Einstein renounced German citizenship. He was appointed life member of the Institute of Advanced Studies, Princeton, New Jersey. He was offered the Presidency of Israel but he declined. He received the Franklin Institute Medal in 1935. During the Second World War, Einstein was persuaded by his colleagues to write a letter to President Roosevelt urging him to put into effect a gigantic research programme designed to develop a nuclear bomb. The project was sanctioned and was successfully completed.

Einstein authored several books like *Meaning of Relativity, 1923; Sidelights on Relativity, 1923; Investigation of Theory of Brownian Movement, 1926; Builders of the Universe, 1932; On the method of Theoretical Physics, 1933; Why War?, 1933; The World as I see It, 1934;* and *Evolution of Physics, 1938.* Apart from these books, he published many articles on different scientific subjects.

The main source of recreation for Einstein was music and he was an excellent violinist. He died on 18April 1955 at Princeton, New Jersey at 76 years of age.

Check Your Progress

1. Name the theory devised by Albert Einstein.
2. When did Albert Einstein receive the Nobel Prize?
3. Mention the literary works of Albert Einstein.

10.3 ROENTGEN

Wilhelm Conard Roentgen was born to Friedrich Conard Roentgen and Charlotte Constanze Frowein on 27 March 1845, at Lennep in Germany. He attended high school at Utrechet Technical School in Utrechet, Netherlands from where he was, however, unfairly expelled. Later he passed the entrance examination of Federal Polytechic Institute in Zurich and pursued mechanical engineering. He graduated with a Ph.D. from the University of Zurich in 1869.



Fig 10.2 *Wilhelm Conard Roentgen*

Source: *https://commons.wikimedia.org/wiki/File:Roentgen2.jpg*

In 1874, Roentgen joined as a lecturer at the University of Strasbourg. In 1875, he became a Professor at the Academy of Agriculture at Hohenheim, Wurttemberg. In 1876, he returned to Strasbourg as a Professor of Physics, and in 1879, he was appointed to the Chair of Physics at the University of Giessen. He obtained the physics chair at the University of Wurzburg in 1888 and in 1900 at the University of Munich.

10.3.1 Discovery of X-Rays

The discovery of X-rays by Roentgen was a momentous event that instantly revolutionized the fields of physics and medicine. In 1895, he was studying the phenomena associated with the passage of an electric current through a gas of extremely low pressure. Early labours in this field had already been done by J. Plucker (1801-1868), J. W. Hittorf (1824-1914), C. F. Varley (1828-1883), E. Goldstein (1850-1931), Sir William Crookes (1832-1919), H. Hertz (1857-1894) and Ph. von Lenard (1862-1947), and by their work the properties of cathode rays had become famous.

On 8 November 1895, Roentgen observed that when he shielded the tube with heavy black cardboard, the green fluorescent light caused a platino-barium screen 9 feet away to glow too far away to be reacting to the cathode rays. He concluded that fluorescence was caused by invisible rays originating from the Crookes tube he was using to study cathode rays, which penetrated the heavy black paper wrapped around the tube. Experiments conducted later on revealed that this new type of ray was capable of passing through most substances, including the soft tissues of the body, but left shadows of solid objects rendering bones and tissue beneath visible. Since he was unaware of the nature of these rays, he named them using mathematical designation 'X', meaning 'unknown' rays. After about six weeks of his discovery, he took a picture—a radiograph—using X-rays of his wife's hand. When she saw her skeleton she exclaimed 'I have seen my death!'

For testing his observations and enhancing his scientific data, Roentgen conducted further experiments. On 28 December 1895, in the Proceedings of the Wurzburg Physico-Medical Society, he submitted his paper, *On a New Kind of Rays*. He made his first public presentation before the same society in January 1896. He made a plate of the hand of an attending anatomist, who proposed the new discovery be named Roentgen's Rays. The University of Wurzburg awarded him an honourary Doctor of Medicine degree after his discovery.

The news of this great discovery spread rapidly worldwide. Thomas Edison developed a handheld fluoroscope. The apparatus for producing X-rays was soon widely available, and studios opened to take 'bone portraits,' further increasing public interest and imagination. Within a year, doctors in Europe and the United States were using X-rays to locate bone fractures, gun shots, kidney stones and swallowed objects. The first angiography, moving-picture X-rays, and military radiology was done in early 1896.

Thus, medical use of X-rays flourished, with hardly any regard for potential side effects from exposure to radiation. Early use of X-rays was extensive and uninhibited, even to the degree that during the 1930s and 1940s, shoe shops offered free X-rays so that customers could see the bones in their feet. Apart from the diagnostic powers of X-rays, some experimentalists started using X-rays for treating the disease.

Numerous honours were showered on Roentgen. In many cities, streets were named after him. He received the first Nobel Prize in Physics in 1901 for his discovery. He refused to take out patents for X-rays as he wanted the society to be freely benefitted. He rejected a title that would ensure his place into the German nobility and donated his Nobel Prize money to his university. His humanity, however, came at considerable personal cost. As a result of inflation following the First World War, he fell into bankruptcy. He died on 10 February 1923 from carcinoma of the intestine. Today, Roentgen is regarded as the Father of Diagnostic Radiology, the medical specialty which uses imaging to diagnose diseases.

Check Your Progress

4. In which year did Wilhelm Roentgen become a Professor at the Academy of Agriculture at Hohenheim, Wurttemberg?
5. When did Roentgen receive the Nobel Prize?

10.4 MARIE CURIE

Marie Curie (maiden name, Maria Salomea Sklodowska) was a Polish-born French physicist. She has been the subject of numerous biographical works, where she is also known as Madame Curie. She was born on 7 November 1867 at Warsaw, Poland. She was the fifth and youngest child of famous teachers Bronislawa, *née* Boguska, and Wladyslaw Sklodowski. Since childhood she was renowned for her prodigious memory.



Fig 10.3 *Marie Curie*

Source:*https://commons.wikimedia.org/wiki/Maria_Sk%C5%82odowska Curie#/media/File:Marie_Curie_(Nobel-Chem).jpg*

She was compelled to work as a teacher because her father, a teacher of mathematics and physics, suffered financial loss due to bad investment. She also worked as a governess, where she suffered an unhappy love affair. From her earnings, she helped her sister to pursue medical studies in Paris.

In 1891, Maria Salomea Sklodowska left Poland for France with the name Marie. While in Paris, she began to follow the lectures of Paul Appel, Gabriel Lippmann and Edmond Bouty at the Sorbonne. There she met Jean Perrin, Charles Maurain, and Aime Cotton who were renowned physicists of that time. Marie studied during the day and tutored in the evenings and virtually lived on bread and butter and tea. She was awarded a degree in physics in 1893. She began to work in Lippmann's industrial laboratory and in 1894 was placed second in the *licence* of mathematical sciences. She met Pierre Curie, who was a Professor at Sorbonne, in the same year. It was their mutual passion in natural sciences that brought them together. They were married on 26 July 1895.

10.4.1 Radioactivity

In 1895, Roentgen discovered the existence of X-rays and in 1896 Henri Becquerel discovered a new phenomenon (which was later on known as 'radioactivity'). Marie Curie, looking for a subject for a thesis, decided to investigate if the property discovered in uranium was to be found in other matter. She found that this was true for thorium at the same time as Gerhard Carl Schmidt. Then she got interested in the minerals, particularly pitchblende, which is a crystalline form of uranium oxide. Its superiority to that of pure uranium, could be explained only by the presence of small quantities of an unknown substance of very high activity in the ore. Pierre Curie and Marie Curie then worked together to resolve this problem and that led to the discovery of the new elements, polonium and radium. Marie Curie coined the term 'radioactivity' to describe this new phenomenon. While Pierre Curie devoted himself mainly to the physical study of the new radiations, Marie Curie worked hard to get pure radium in the metallic state. She was able to achieve this with the help of the chemist Andre-Louis Debierne, one of Pierre Curie's pupils. Marie and Pierre Curie published 32 scientific papers between 1898 and 1902, jointly or separately, including one that announced that, when exposed to radium, diseased, tumour-forming cells were destroyed faster than healthy cells. For her research, Marie Curie was awarded doctorate of science from the University of Paris in June 1903 and Pierre was conferred with the Davy Medal of the Royal Society. In December 1903, the Royal Swedish Academy of Sciences awarded Pierre Curie, Marie Curie and Henri Becquerel the Nobel Prize in Physics for the discovery of radioactivity. Marie Curie was the first woman recipient of the Nobel Prize.

The accidental death of Pierre Curie on 19 April 1906 was a severe blow to Marie Curie, but it was also a decisive turning point in her career. Henceforth, she began to devote all her energy to single-handedly completing the scientific work that they had undertaken together. On 13 May 1906, she was appointed as

Professor at the University of Paris. Later on, she also headed the Radium Institute at the University of Paris. In 1910, Curie succeeded in isolating radium. In 1911, the Royal Swedish Academy of Sciences honoured her a second time with the Nobel Prize in Chemistry. Throughout the First World War, Marie Curie, with the help of her daughter Irene, devoted herself to the development of the use of X-radiography.

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Marie Curie devoted her researches to the study of the chemistry of radioactive substances and their medical applications. In 1921, accompanied by her two daughters, Marie Curie made a triumphant journey to the United States to raise funds for research on radium. She also travelled to other countries and gave lectures. In 1922, she was made a member of the Academy of Medicine and also served as a member of the International Commission on Intellectual Co-operation by the Council of the League of Nations. Marie Curie also understood the need to gather intense radioactive sources, not only to treat illness but also to maintain an abundant supply for research in nuclear physics. The resultant stockpile was an unrivaled instrument until the appearance after 1930 of particle accelerators. Her work paved the way for the discovery of the neutron by Sir James Chadwick and, above all, for the discovery of artificial radioactivity by Irene and Frederic Joliot-Curie. A few months after this discovery, Marie Curie died on 4 July 1934 at the Sancellemoz sanatorium in Passy, Haute-Savoie as a result of aplastic anemia caused by the long-term exposure to radiation. The harmful effects of ionizing radiation were unknown at the time of her work, which had been carried out without the safety measures later developed.

Check Your Progress

6. What was Marie Curie's maiden name?
7. Name the first woman to receive the Nobel Prize in the history of mankind.

10.5 RUTHERFORD

Ernest Rutherford was a physicist from New Zealand who was born on 30 August 1871 to James Rutherford and Martha Thompson. He received his initial education at Havelock School. He won a scholarship to attend Nelson Collegiate School. With the help of another scholarship he went to study at Canterbury College, University of New Zealand. After completing his BA, MA and BSc, and 2 years of research during which he invented a new form of radio receiver, in 1895 he was awarded Research Fellowship to travel to England for postgraduate study at the Cavendish Laboratory, University of Cambridge. He was allowed to do research at the university, under the leadership of J. J. Thomson, who was Europe's leading expert on electromagnetic radiation. With Thomson's encouragement, he managed to detect radio waves at half a mile and briefly held the world record for the distance over which electromagnetic waves could be detected.

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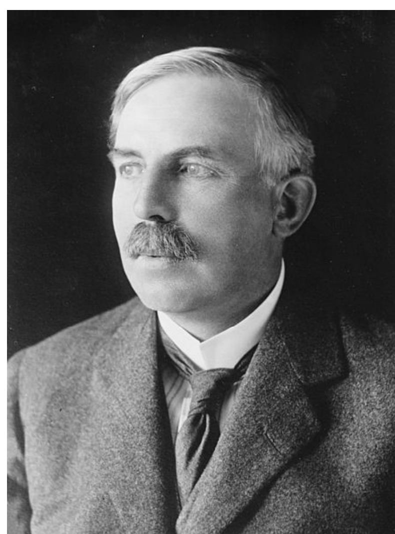


Fig 10.4 *Ernest Rutherford*

Source: *https://commons.wikimedia.org/wiki/File:Ernest_Rutherford_LOC.jpg*

Rutherford became the first research student of a research project at the University of Cambridge. Besides showing that an oscillatory discharge would magnetize iron, which was already known, Rutherford determined that in a magnetic field produced by an alternating current the magnetized needle lost some of its magnetization. This made the needle a detector of electromagnetic waves. In 1864, James Clerk Maxwell, the Scottish physicist, had predicted the existence of such waves and between 1885 and 1889 the German physicist Heinrich Hertz had detected them in experiments in his laboratory. Rutherford's apparatus for perceiving electromagnetic waves, or radio waves, was simpler. He also spent one year in the Cavendish Laboratory conducting experiments for increasing the range and sensitivity of his device, which could receive signals from half a mile away. However, it was an Italian inventor Marconi, who invented the wireless telegraph in 1896.

German physicist Roentgen discovered X-rays only a few months after Rutherford arrived at the Cavendish. Rutherford accepted Thomson's invitation to collaborate on an investigation of the way in which X-rays altered the conductivity of gases. It resulted in an excellent paper about dividing atoms and molecules into ions.

Thomson then examined what would later be called electron, while Rutherford carried his work on other radiations that produced ions such as ultraviolet radiation and radiation emitted by uranium. When Rutherford placed uranium near thin foils he found that one type was easily absorbed or blocked by a very thin foil, but another type often penetrated the same thin foils. He labelled these two radiations types as alpha and beta. Later on, it was found that the alpha particle was identical to the nucleus of an ordinary helium atom—having two protons and two neutrons—and the beta particle is the same as an electron or positron.

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In 1902 Rutherford left Cambridge and took up a professorship at McGill University, Montreal. Here Rutherford and his colleague discovered that thorium emitted a gaseous radioactive product, which he termed as 'emanation'. This in turn left a solid active deposit, which soon was resolved into thorium A, B, C, and so on. Upon chemical treatment, some radioactive elements lost their radioactivity but ultimately regained it, while other materials, initially strong, gradually lost their activity. This led to the concept of half-life.

In 1902-03 Rutherford along with Frederick Soddy, a Yale University Professor, developed the transformation theory, or disintegration theory of radioactivity which was his greatest accomplishment at McGill. Rutherford and Soddy claimed that the energy of radioactivity came from within the atom, and the spontaneous emission of an alpha or beta particle signified a chemical change from one element into another.

Earlier it was believed that the radio-elements fell into three families, or decay series, headed by uranium, thorium, and actinium and all leading to an inactive lead. On Rutherford's suggestion Boltwood placed radium in the uranium series and used the slowly growing amount of lead in a mineral to show that the age of old rocks was in the billion-year range. Rutherford regarded the alpha particle to be key to transformations. He determined that it carried a positive charge, but he was not able to differentiate whether it was a hydrogen or helium ion.

Rutherford returned to England in 1907 and joined the University of Manchester as a Professor. Through his experiments he made a significant discovery that nearly the total mass of an atom is concentrated in the nucleus. In doing so, he proposed a nuclear model. This discovery led to the inception of nuclear physics and subsequently paved the way to the invention of atom bomb. In 1908, he received the Nobel Prize for Chemistry.

Rutherford also developed an electrical counter for ionized particles along with German physicist Hans Geiger. It was perfected by Geiger and came to be known as the Geiger counter. It became the universal tool for measuring radioactivity. Rutherford and his student Thomas Royds isolated some alpha particles and performed a spectro-chemical analysis, proving that the particles were helium ions. Rutherford and Boltwood re-determined the rate of production of helium by radium, from which they calculated a precise value of Avogadro's number.

In 1911, Rutherford conceived that the atom could not be a uniform solid but rather consisted mostly of empty space, with its mass concentrated in a tiny nucleus. However, this theory did not receive much attention. Danish physicist Neil Bohr in 1913, however, showed its importance. English physicist Henry Moseley explained the sequence of the X-ray spectrum of elements due to the charge on the nucleus. Thus, a comprehensible new picture of atomic physics, as well as the field of nuclear physics, was developed.

With the commencement of World War I, Rutherford laboratory got engaged in an antisubmarine research. He also examined the collision of alpha particles with gases. In 1919 Rutherford had made another great discovery. He had artificially induced a nuclear reaction in a stable element. Nuclear reactions remained his main focus for the remaining part of his career which was spent at the University of Cambridge, where he succeeded Thomson as the Director of the Cavendish Laboratory.

On 19 October 1937, Rutherford died in Cambridge, England at the age of 66 from short illness due to strangulated hernia. The scientist, who had been nicknamed 'Crocodile' by his colleagues for always looking ahead, was buried at Westminster Abbey. He is dubbed as the Father of the Nuclear Age.

Check Your Progress

8. Who invented the wireless telegraph?
9. What was the 'Geiger counter'?

10.6 ATOM BOMB

Atom bomb is a weapon with enormous explosive power that is caused due to sudden powerful release of energy upon the splitting, or fission, of the nuclei of a heavy element such as plutonium or uranium. Atomic bombs derive their energy from fission reactions. Thermonuclear weapons, or hydrogen bombs, depend on a combination of nuclear fission and nuclear fusion. In nuclear fusion two lighter atoms combine to release energy.

The first atomic bomb was built in Los Alamos, New Mexico, during the Second World War under a programme called the Manhattan Project. It was the code name for the US led effort to develop a functional atomic bomb. It was started under the direction of theoretical physicist J. Robert Oppenheimer in response to fears that the scientists of Germany were engaged in making a weapon using nuclear technology since the 1930s.

Oppenheimer, the 'Father of the Atomic Bomb', was born in New York City on 22April 1904. He was the son of a German immigrant who used to import textiles in the New York City. During his undergraduate studies at Harvard University, Oppenheimer made a mark in Latin, Greek, physics, and chemistry, published poetry and studied Eastern philosophy. After completing his graduation in 1925, he went to England to do research at the Cavendish Laboratory at the University of Cambridge. Here, he got an opportunity to collaborate with the British scientific community in its efforts to advance the cause of atomic research.

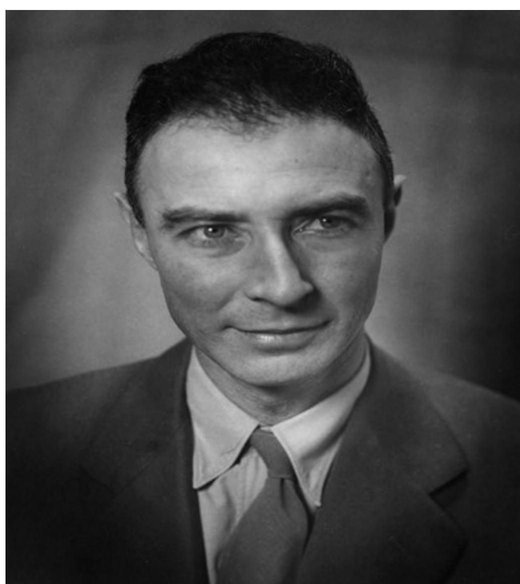


Fig 10.5 *J. Robert Oppenheimer*

Source:*https://commons.wikimedia.org/wiki/Category:J._Robert_Oppenheimer#/media/File:Oppenheimer_Los_Alamos_portrait.jpg*

In 1926, Oppenheimer was invited to the University of Gottingen to study under Max Born, where he met some prominent physicists, such as Niels Bohr, Enrico Fermi and Paul Dirac, and where, in 1927, he obtained his Doctor of Philosophy. He returned to the United States to teach physics at the University of California at Berkeley and the California Institute of Technology.

In the second decade of the 20th century the new quantum and relativity theories were engaging the attention of science. That mass was equivalent to energy and that matter could be both wavelike and corpuscular carried implications seen only dimly at that time. Oppenheimer carried out his initial research especially in energy processes of subatomic particles, including electrons, positrons and cosmic rays. He also did revolutionary work on neutron stars and black holes.

When Germany invaded Poland in 1939, several physicists warned the US government of the danger threatening humanity if the Nazis should be the first to make a nuclear bomb. Oppenheimer then started looking at a process for the separation of uranium-235 from natural uranium and to determine the critical mass of uranium which was required to make such a bomb. In August 1942, the US Army was assigned the responsibility of organizing the efforts of British and US physicists to find a way to harness nuclear energy for military purposes, an effort that came to be known as the Manhattan Project. For this purpose, Oppenheimer was instructed to establish and administer a laboratory. In 1943, he chose the plateau of Los Alamos, New Mexico.

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The combined efforts of the scientists at Los Alamos led to the first nuclear explosion on 16 July 1945, in a remote desert location at the Trinity Site near Alamogordo, New Mexico, after the surrender of Germany. It resulted in an enormous mushroom cloud which was about 40,000 feet high and ushered in the Atomic Age. The test was final, terrible proof that nuclear energy could be utilized to create deadly weapons, and prompted Oppenheimer to recall a passage from the Bhagavad Gita: 'I am become death, the destroyer of worlds.' The atom bomb attacks on Hiroshima and Nagasaki in Japan triggered the worldwide arms race.

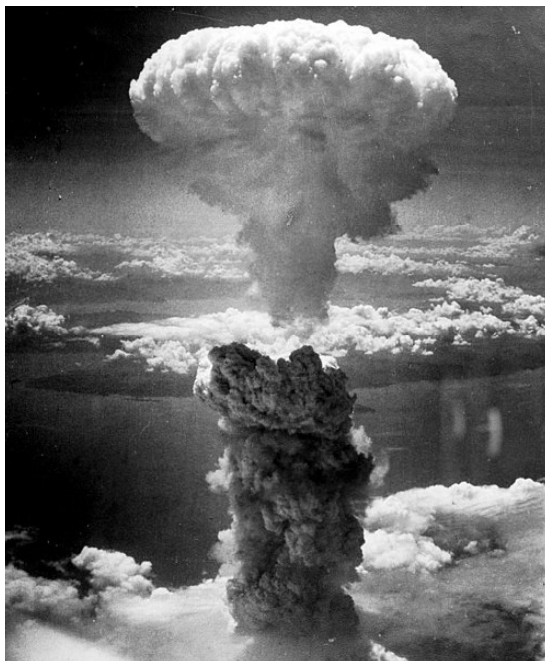


Fig 10.6 *Nagasaki Bombing*

Source: *https://commons.wikimedia.org/wiki/File:Nagasakibomb.jpg*

In October 1945, Oppenheimer resigned from his post. In 1947 he became head of the Institute for Advanced Study and between 1947 and 1952 served as the Chairman of the General Advisory Committee of the Atomic Energy Commission, which in October 1949 opposed development of the hydrogen bomb.

In 1953 Oppenheimer's suspicious behaviour led to the cancellation of his contract as adviser to the Atomic Energy Commission. However, the Federation of American Scientists immediately came to his defence with a protest against his trial. He spent the latter years of his life working out ideas on the relationship between science and society. In 1963, US President Lyndon B. Johnson presented Oppenheimer with the Enrico Fermi Award of the Atomic Energy Commission. In 1966, Oppenheimer retired from the Institute for Advanced Study in 1966 and died of throat cancer at his home in Princeton, New Jersey on 18 February 1967 at the age of 62.

Check Your Progress

10. When and where was first atomic bomb developed in the world?
11. When did Oppenheimer receive the Enrico Fermi Award?

10.7 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Albert Einstein devised the theory called the theory of Relativity.
2. In 1921, Einstein got the Nobel Prize in Physics for suggesting applications of the Quantum mechanics.
3. Einstein authored several books like *Meaning of Relativity, 1923; Sidelights on Relativity, 1923; Investigation of Theory of Brownian Movement, 1926; Builders of the Universe, 1932; On the method of Theoretical Physics, 1933; Why War?, 1933; The World as I see It, 1934;* and *Evolution of Physics, 1938*. Apart from these books, he published many articles on different scientific subjects.
4. In 1875, he became a Professor at the Academy of Agriculture at Hohenheim, Wurttemberg.
5. Wilhelm Roentgen received the first Nobel Prize in Physics in 1901 for his discovery.
6. Marie Curie's maiden name is Maria Salomea Sklodowska.
7. Marie Curie is the first woman in the history of mankind to receive the Nobel Prize for discovery in the field of Physics.
8. Italian inventor Marconi invented the wireless telegraph in 1896.
9. Geiger counter became the universal tool for measuring radioactivity. Rutherford developed an electrical counter for ionized particles along with German physicist Hans Geiger. It was perfected by Geiger and came to be known as the Geiger counter.
10. The first atomic bomb was built in Los Alamos, New Mexico, during the Second World War under a programme called the Manhattan Project. It was the code name for the US led effort to develop a functional atomic bomb.
11. In 1963, US President Lyndon B. Johnson presented Oppenheimer with the Enrico Fermi Award of the Atomic Energy Commission.

10.8 SUMMARY

NOTES

- In the 19th and 20th century there were great advancements in the field of science. The 19th century has sometimes been called the Age of Science. There were new and radical developments in physics and chemistry.
- Albert Einstein was a German physicist who contributed to science by developing the Special Theory of Relativity in 1905 and Theory of General Relativity in 1915.
- He gave the famous equation of scienceE = mc^2 which implies 'energy equals mass times the speed of light squared' i.e., the energy of a body is equal to the mass of the body multiplied by the square of the speed of light. The equation infers that matter can be changed into energy and energy into matter.
- The German physicist, Wilhelm Conrad Roentgen was the first person to systematically produce and detect electromagnetic radiation in a wavelength range today called as X-rays or Roentgen rays. Today, Roentgen is considered the father of diagnostic radiology, the medical speciality which uses imaging to diagnose diseases.
- Marie Curie was a Polish-born French physicist who is remembered for her discovery of radium and polonium, and her immense contribution in finding treatment for cancer. She was awarded the Nobel Prize in Physics in 1903 and Chemistry in 1911.
- Ernest Rutherford was a physicist from New Zealand who discovered alpha and beta rays, proposed the laws of radioactive decay, and identified alpha particles as helium nuclei. His most important contribution was his postulation of the nuclear structure of the atom. He is called the father of the Nuclear Age.
- The first atomic bomb was built in Los Alamos, New Mexico, during the Second World War under a programme called the Manhattan Project. It was started under the direction of theoretical physicist J. Robert Oppenheimer in response to fears that the scientists of Germany were engaged in making a weapon using nuclear technology since the 1930s.
- The combined efforts of the scientists at Los Alamos led to the first nuclear explosion on 16 July 1945, in a remote desert location at the Trinity Site near Alamogordo, New Mexico.

10.9 KEY WORDS

- **Half-life:** It is the time required for one-half of the unstable nuclei in a radioactive substance to decay into a new element.
- **Nuclear fission:** It is a process in nuclear physics in which the nucleus of an atom splits into two or more smaller nuclei as fission products, and usually some by-product particles.
- **Quantum mechanics:** It is a basic theory in physics that provides a description of the physical properties of nature at the scale of atoms and subatomic particles.
- **Radioactivity:** The emission of ionizing radiation or particles caused by the spontaneous disintegration of atomic nuclei.

10.10 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Write a short note on the life of Albert Einstein.
2. Prepare a brief sketch of the life of Wilhelm Conard Roentgen.
3. Mention the significant contribution of Madame Curie in the field of physics.

Long-Answer Questions

1. Discuss the contribution of Einstein with special reference to the theory of Relativity.
2. Analyse the invention of the X-ray by Roentgen as a significant contribution to the field of science and technology.
3. 'Rutherford is known as the father of Nuclear Age.' Explain.
4. How did the invention of the atom bomb change the course of world history?

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NOTES

UNIT 11 SCIENCE AND TECHNOLOGY IN THE 20TH CENTURY II

Structure

11.0 INTRODUCTION

A considerable number of new technologies were developed during the 20th century. Nuclear weapons signify the ultimate defence of a nation, a deterrent against any and all potential adversaries. They have aided in avoiding a large-scale conflict between leading world powers for a very long time. Hydrogen bomb is a second-generation nuclear weapon design.

Radio and television brought news and entertainment into the home, while at the end of the 20th century the World Wide Web connected people, news and entertainment through personal computers. As a result of the emergence and development of the Internet, a universal information environment has appeared, characterized by a high degree of interactivity, availability of information, the efficiency of information exchange, and ease of transfer of information. E-mail is a great means of communication. The wireless technology Wi-Fi has become indispensable for home networking, public internet connectivity, supporting the connecting of things and much, much more.

11.1 OBJECTIVES

NOTES

After going through this unit, you will be able to:

- Discuss the events leading to the invention of the hydrogen bomb
- Learn about the development of radio technology
- Explain the development of Radar, its working principle, uses, limitations and benefits
- Assess the evolution of television
- Discuss the invention and uses of computer
- Describe the invention and applications of Internet
- Prepare an account of the invention, features, needs and uses of email
- Know the principle, advantages and limitations of Wi-Fi system

11.2 HYDROGEN BOMB AND ATOMIC ENERGY

Hydrogen bomb is a kind of nuclear weapon, also called as the 'superbomb,' that derives some of its energy from the fusion of the nuclei of light elements, typically isotopes of hydrogen. It is accompanied with the release of enormous energy.

Since the reaction occurs only at very high temperatures therefore it is necessary to have an external source of energy to provide the required high temperature. So atom bomb (i.e., fission bomb) is used as a primer, which by exploding provides the required high temperature for successful working of hydrogen bomb (i.e., fusion bomb). For preparing hydrogen bomb, an appropriate amount of deuterium or tritium or a mixture of both is enclosed in a space surrounding an ordinary atomic bomb. A hydrogen bomb is much more powerful than an atom bomb.

As early as 1938, the scientists recognized that the fusion or thermonuclear reaction was the source of the Sun's energy. During the Second World War, scientists of the Manhattan Project saw the possibility of making a thermonuclear weapon, but they decided to concentrate first on building a fission or atomic bomb because any fusion bomb would likely require a fission device to initiate its thermonuclear burning.

Although the United States had developed and used the atomic bomb by 1945, only modest theoretical research on fusion was done before the first Soviet atomic test of August 1949. A number of scientists of the US Atomic Energy Commission and its General Advisory Committee opposed development of the hydrogen bomb on both practical and moral grounds, but advocates within

Congress, the military, and elsewhere argued that any limitation shown by the United States in the matter would not be responded well by a Soviet Union still ruled by Joseph Stalin.

The first hydrogen bomb was tested at Eniwetok atoll on 1 November 1952 by Edward Teller, Stanislaw M. Ulam, and other US scientists. On 12 August 1953, the Soviet Unionhttps://www.britannica.com/place/Soviet-Union first tested a hydrogen bomb followed by the Britain in May 1957 China (1967), and France (1968). By the 1960s, mainly due to the hydrogen bomb, both United States and Soviet Union had acquired the ability to destroy as much of the other as they wished in a very short time. The world had entered the era of 'mutual assured destruction'.

India tested a 'thermonuclear device', in 1998 which was believed to be a hydrogen bomb. During the late 1980s there were some 40,000 thermonuclear devices stored in the arsenals of the world's nuclear-armed nations.

Check Your Progress

1. In which year did India test a hydrogen bomb?
2. When was the first hydrogen bomb tested in the history of the world?

11.3 RADIO

Radio is a field of technology that deals with the transmission of information over distances by means of radio waves. Radio waves are electromagnetic waves that have been in existence ever since the beginning of the universe. Radio waves, thermal radiation, ultraviolet (UV), X-rays, gamma rays—all are electromagnetic waves that differ only in the frequency of oscillations.

Radio works because electromagnetic waves possess the ability to pass through the air. Sound is converted into such electromagnetic signals which are then sent out or broadcasted from stations and received in special boxes which are tuned to a particular frequency and which reconvert the sound signal into voice again.

The radio came from a sequence of discoveries and inventions in the late 19th and the early 20th century. In November 1886, German physicist Heinrich Hertz became the first person to transmit and receive controlled radio waves. He studied radio waves and proved that signals could be transmitted wirelessly. Radio wave frequencies are still measured in Hertz today after his name.

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Fig 11.1 *Heinrich Hertz*

Source:https://commons.wikimedia.org/wiki/File:Heinrich_Rudolf_Hertz.jpg

However, the issue of first inventor of the radio is a debatable one. In 1894, an Italian inventor and businessman Guglielmo Marconi designed a device capable of ringing a bell from 30 feet away. On the other hand, a year prior to Marconi's demonstration, Nikola Tesla, a Serbian immigrant to the United States, demonstrated a wireless radio to audiences in St. Louis. Although Tesla came first, Marconi patented his invention in 1896 while Tesla patented his invention in 1900. Marconi transmitted the first signal to cross the Atlantic from Europe to America in 1901. It was a historic moment in the field of communication because it signaled that soon voice could also be transmitted across space wirelessly. By the year 1906, music was being transmitted across longer distances. The first commercial radio station had come up by 1909 and ten years later the first radio stations were established in the United States. Soon private radio stations and universities and governments started using this new and affordable medium which reached the masses.

Other inventors contributed to the advancement of the technology. Ernst Alexanderson, a Swedish born inventor, invented the first alternator capable of transmitting speech, which Reginald Fessenden used to combine radio waves and sound for the first long-range transmission of a human voice. Finally, Edwin Armstrong introduced the continuous-wave transmitter and amplifying receiver, making FM (Frequency Modulation) radio possible for the first time.

Radio technology was initially used in aboard seagoing ships, with the objective of helping them communicate with nearby vessels and the shore. The earlier ships depended on semaphore flags to send messages between ships and carrier pigeons for longer-distance communication. In the Titanic disaster, radio was directly responsible for the distress signal and rescue response. No one would have survived without radio. The radio was also used in the aviation sector when in 1910; Frederick Baldwin and John McCurdy used it on their bi-plane. In Detroit ,the radio became part of public safety vehicles in 1921.

Check Your Progress

3. Radio frequencies are measured in which Unit?
4. In which year did Guglielmo Marconi patent his invention?

11.4 RADAR

The full form of Radar is Radio Detection and Ranging. It is a system that provides microwave segment or ultra-high frequency of the radio spectrum to identify obstacles to control the area of the spot or range of an object. It can locate a faraway object and explore or identify the speed of an object. During World War II, it had been secretively planned and produced by several countries.

Work on Radar system started in the third decade of the 20th century. Robert Watson-Watt, a Scottish scientist, developed a Radar system in 1935. It was used to help protect Britain from air attacks. During the Second World War, Radar helped Britain, France, and the United States defeat Germany. Since then a number of improvements have been made in Radar technology. Today, computers help Radar systems provide more details about faraway objects.

11.4.1 Working Principle of Radar

A Radar system is made up of a transmitter, a display, an antenna and a receiver. The transmitter generates radio waves, which are invisible streams of energy. The antenna sends the waves out into the air. When the waves strike an object, they reflect, or bounce back, to the antenna. The waves then pass to the receiver, which makes sense of them. By measuring how long it takes the waves to return, the receiver determines how far away the object is. The receiver can also judge the direction and speed of the moving object. Sometimes, it is also able to sense the size of the object. The receiver sends this information to a display, or screen, for people to see.



Fig 11.2 *Radar*

Source:https://commons.wikimedia.org/wiki/Radar#/media/File:Radar_antenna.jpg

11.4.2 Applications of Radar

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Radars are widely used in military operations. They are used in naval, ground as well as air defence purposes. Militaries rely on Radar to find and track their targets. The air traffic controllers at airports use Radar to keep track of the airplanes and direct their movements. The ships and airplanes use Radar to navigate, or find their way. Radars are used to track and detect satellites and spacecraft. During bad weather conditions, Radar is used to guide aircraft for proper landing and take-off. Law enforcement, especially highway police, has extensive use of Radar to spot speeding vehicles. It is also used by the weather forecasters to locate storms and predict the weather.

Benefits of Radar

Radars can penetrate mediums like fog, snow, clouds and mist. Signals from Radars can pass through isolators. It has the ability to locate an object accurately. It is able to assess the target speed. It can aid in measuring the distance of an object. It can determine the disparity between stationary and moving objects. Radar signals do not involve a carrying medium.

Limitations of Radar

Radar involves a considerable amount of time to set a lock on an entity. It also has a wider beam size over 50 feet diameter. The Radar has a limited range of 200 feet. A number of objects and mediums may interact in the air with Radar. Itcannot detect multiple targets, or come up with a solution.

Check Your Progress

5. When and by whom was the Radar system developed?
6. Mention any two applications of the Radar system.

11.5 TELEVISION

Television is a system for transmitting visual images and sounds that are reproduced on screens, essentially used to broadcast programmes for entertainment, education and information. The television is one of the most noticeable inventions of the 20th century. It has become one of the most popular means people view the larger world beyond them, in addition to being one of the best ways for people to escape from the world. The concept of television was the work of many individuals in the late 19th and early 20th centuries. A German inventor in the late 19th century produced simple moving images using a filtered light viewed by means of a spinning disk. This laid the foundations for the modern television. In the second decade of the 20th century, many scientists started experimenting by sending still images

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using radio waves. On 26 January 1926, a Scottish inventor, John Logie Baird, gave the first public demonstration of a true television system in London. However, it was in 1928 that Baird made the first overseas broadcast from London to New York and demonstrated the first colour television.

In the same year, the first home television receiver was displayed in Schenectady, New York and a station started occasional broadcasts to a few homes in the area that were provided with the General Electric-built machines.

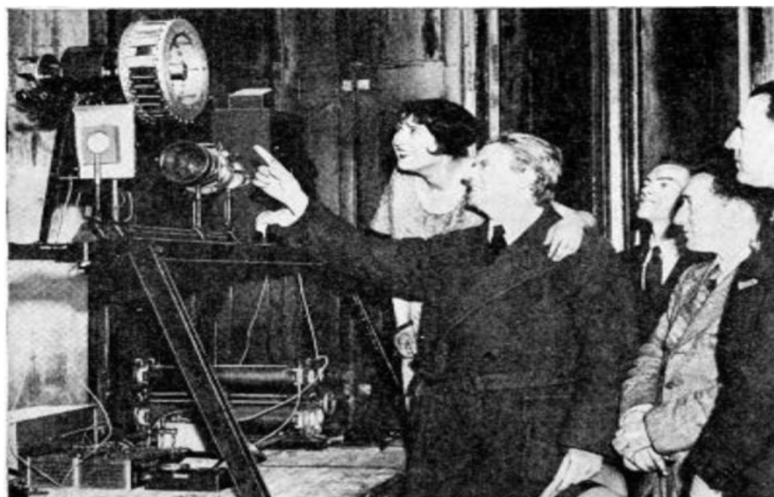


Fig 11.3 *John Logie Baird with Mechanical Television*

Source:https://commons.wikimedia.org/wiki

During the 1930s and 1940s there was a gradual improvement in technology. In 1932, the United States Radio Corporation demonstrated an all-electronic television using a cathode-ray tube in the receiver and the 'iconoscope' camera tube developed by Vladimir Zworykin, who was a Russian-born physicist. In 1936, the British Broadcasting Corporation (BBC) started regular high-definition public broadcasts in London. There was a considerable improvement in the picture quality as a result of these two inventions. Regular broadcasts began in the United States in 1939 though it was not until after the Second World War that the television as a standard home appliance began to really take off. After 1945, television sales in United States rose steeply. Permanent color broadcasts started in 1954.

Television became available to the the rest of the world years later, and it was not until the late 1960s that a television was common in houses throughout the West. By the 1970s, television had become a foremost media force, with 24 hour programming, mass advertising and syndicated shows. In the 1980s satellite television shrunk the world, making live feeds from other countries and time zones possible. The new millennium brought the advent of digital television, which is the future of television.

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Check Your Progress

7. In which year did BBC begin making regular public broadcasts through television?
8. When and where was the first colour television demonstrated?

11.6 COMPUTER

A computer is a device that accepts data as input, processes that data using programs, and outputs the processed data as information. Man have been using a number of devices from times immemorial. One of the earliest and renowned devices was an abacus. Then in 1822, the Father of Computers, Charles Babbage started developing the first mechanical computer. And then, in 1833, he actually designed an Analytical Engine which was a general purpose computer.

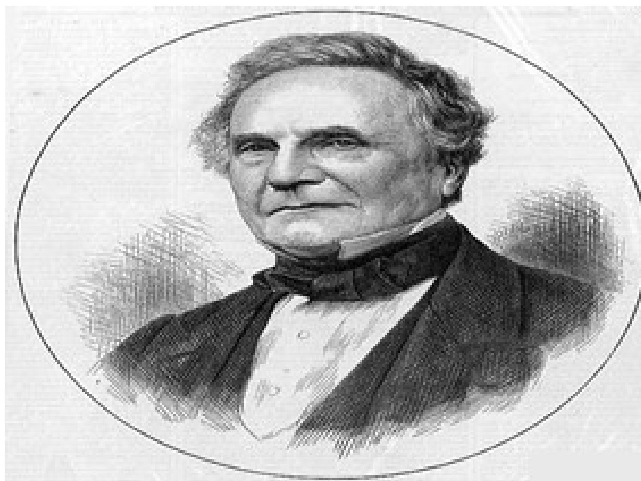


Fig 11.4 *Charles Babbage*

Source: https://commons.wikimedia.org/wiki/File:Charles_Babbage_1860.jpg

A computer together with hardware and software is called a computer system. A computer system consists of a Central Processing Unit (CPU), memory, input/output devices and storage devices. All these components work together as a single unit to deliver the required output. A computer system occurs in various forms and sizes. It can vary from a high-end server to personal desktop, laptop, tablet computer, or a Smartphone.

11.6.1 Uses of Computer

Computers play a significant role in every field of life. They are used in homes, schools, colleges, research organizations, business, medical field, government offices, entertainment, etc.

(i) Home

Computers are used at homes for a number of purposes such as playing games, Internet access, online bill payment, watching movies or shows, home tutoring, social media access, etc. They provide communication by means of electronic mail. They are used to avail work from home facility for corporate employees. Computers aids in online mode of education as well.

(ii) Education

Computers are widely used in schools and colleges in teaching as well as in non-teaching tasks. They aid in online classes, online examinations, referring e-books, creating projects and assignments, online tutoring, etc. They can also be used to give audio-visual aids to the learners.

(iii) Entertainment

Computers are a great means of entertainment. They help to play games and watch movies online. They act as a virtual entertainer in playing games, listening to music, etc. Musical Instruments Digital Interface (MIDI) greatly help people in the entertainment industry in recording music with artificial instruments. Videos can be fed from computers to big screen televisions. Photo and videos can also be edited.

(iv) Healthcare

In hospitals, the computers are utilized to maintain a database of patients' history, diagnosis, X-rays, live monitoring of patients, etc. Nowadays, robotic surgical devices are used by the surgeons to conduct delicate operations and remote surgeries. For training, virtual reality technologies are also used. It also helps to monitor the foetus inside the mother's womb.

(v) Industry

In the field of industry the computers are used to perform a number of tasks such as managing inventory, designing, creating virtual sample products, interior designing, video conferencing, etc. Numerous products are being sold today to inaccessible corners of the world by means of online marketing.

(vi) Government

In various government departments, computers are used in the processing of data, maintaining a database of citizens and supporting a paperless environment. Defence organizations of various nations have greatly benefitted from computers in their use for missile development, satellites, rocket launches, etc.

(vii) Business

Nowadays, almost every business uses computers. The chief objective of business is processing of transaction which involves transactions with suppliers, employees

or customers. Computers have the ability to make these transactions easy and precise. People can analysesales, investments, expenses, markets and other features of business using computers.

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(viii) Science and Engineering

High performance computers are utilized in stimulating dynamic processes in science and engineering. Supercomputers have several applications in the area of Research and Development (R&D). Computers can be used to create topographic images. They can also be used to plot and analyse data in order to have a better understanding of earthquakes.

(ix) Training

Several organizations use computer-based training to train their employees. This saves a lot of time and money. The concept of video helps save time and facilitates connecting people in various locations.

(x) Banking

In the field of banking, computers are used to store details of customers and conduct transactions, like withdrawal and deposit of money through ATMs. Banks have reduced manual errors and expenses to a great extent through extensive use of computers.

(xi) Arts

Computers are extensively being utilized in photography, dance, arts and culture. The fluid movement of dance can be shown live by means of animation. Photos can be digitized using computers.

(xii) Publishing

Computers are used to design any type of publication like the newsletters, marketing materials, fashion magazines, novels, or newspapers. They are used in the publishing of both hard-copy and e-books. They are also used to market publications and track sales.

Check Your Progress

9. What are the main components of the computer system?
10. State any two applications of computers in our daily lives.

11.7 INTERNET

The Internet is a system of interconnected computer networks that utilizes the Internet protocol suite (TCP/IP) to communicate between networks and devices. It is a network of networks which makes it possible to communicate and

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interact with each other. It comprises private, public, business, academic and government networks, connected by a broad range of electronic, wireless, and optical networking technologies. The Internet was invented by Vinton G. Cerf and Robert E. Kahn in 1974.



Fig 11.5 *Vincent Cerf, Bob Kahn with US President George W. Bush*

Source:https://commons.wikimedia.org/wiki/File:CerfKahnMedalOfFreedom.jpg

The Internet was not developed in a few days or a few months. Rather, it was the result of a long and exhaustive research which took many years. It served as a way for government researchers to share information. In the late 1960s, the computers were large sized and immobile and for the purpose of using information stored in any one computer, one had to either travel to the site of the computer or have magnetic computer tapes sent through the conventional postal system. Department of Defense (DOD) of the United States started a network of devices called ARPANET (Advanced Research Projects Administration Network) with one computer in California and three in Utah. In September 1969, various universities of America were connected by ARPANET. With the gradual increase of the use of the network, other universities, research organizations, and private and commercial establishments also started using this technology. The term 'Internet' was finally coined in 1995 by the FNC (Federal Networking Council, USA).

The working of the Internet is not controlled by any one particular organization but by a group of voluntary organizations who have established the Internet Society. For communication over the Internet, they decided the rules, called as protocols. Various networks may have their own rules that they follow internally, but follow some common rules when they communicate with each other.

11.7.1 Uses of Internet

Internet has become an integral part of our lives. It is extensively used for a wide variety of purposes. A few are mentioned as follows:

(i) Search for Information: Numerous programs called the search engines are available to search for information on any topic. Goggle Chrome, Mozilla,

Bing, Wikipedia, Webopedia, Yahoo etc., are some of the popular search engines. The search is done by typing the question or query for which we are seeking answers or information.

(ii) **E-mail or Electronic Mail:** The Internet is commonly used for sending and receiving e-mails. Message can be sent electronically to any person in the world, provided that the person has an e-mail id. More than 85 per cent of the Internet users send and receive e-mail. It is a fast and economical service.

(iii) **Chatting**: It comprises textual exchange of messages in real time. Chat servers offer facility to make virtual chat rooms and only the members associated with these rooms are allowed to share messages.

(iv) **Instant Messenger Services:** These tools can be utilized to send messages immediately. It also enables us to talk to anyone anywhere in the world. Unlike chatting, it is not necessary to have an account with the same provider. Apart from this, both the users are not required to be connected while sending messages.

(v) **Newsgroup:** It is an e-service hosted by a number of organizations. One can become a member of a newsgroup and read and share current affairs and messages. One such example is Newsnet.

(vi) **Shopping (E-Commerce):** With the growth of the e-commerce industry, our habits of shopping online stuff have evolved a lot. Initially, many people had no faith in the e-commerce website, but that has changed over time. Nowadays, a lot of things are available on the Internet such as clothing, machines, fashion accessories, books, machines, books, technology stuff etc. There are a number of websites where we can buy products and place products for sale as well. Websites such as Amazon, eBay are popular e-commerce sites.

(vii) **Education:** The Internet plays a significant part in effectively shaping today's education system. It has the accessibility and the quality of imparting learning to students as they can study whatever they want and whenever they feel most creative. One can attend classes and take exams online in the confines of home via e-learning.

(viii) **Gaming:** Although online gaming is regarded as entertainment, it deserves to be treated as a distinct category since its surprising growth is visible and impacts the young generation. Online games can be played by multiple players or a single person mode by means of a console, computer or mobile app generally without any cost.

11.7.2 E-Mail

Electronic Mail or E-mail is the transmission of text-based messages from one computer user to one or more recipients by means of a network. It is one of the

most noticeable uses of network communication technology and one of the most commonly used forms of communication today. It is the most popular and quick method of transmitting messages.

E-mail has many advantages over other forms of communication. It is easy to use, free of cost, fast, and delivers information in a digital format. By using appropriate encoding methods, email can be used to send any type of computer file, including pictures, programs, sounds and movies. E-mail started in 1965 as a way for multiple users of a time-sharing processer computer to communicate among themselves. Ray Tomlinson is generally credited as the creator of email as part of a program for ARPANET in 1971. ARPANET played a significant role in popularizing e-mail.



Fig 11.6 *Ray Tomlinson*

Source:https://commons.wikimedia.org/wiki/File:Ray_Tomlinson_(cropped).jpg

There are a number of service providers over World Wide Web (WWW), presenting free e-mail services. However, an organization can offer own mailing service for the stakeholders of the organization. The service is so widespread and effective that a number of organizations operate only on e-mail for internal and external communication.

Features of E-mail

It is a quick and more secure method of communication than the traditional methods. Less physical effort is needed to edit and send a letter of communication. Once the hardware, software, and Internet connection are ready, e-mail on the Internet is free, even if message is to be sent to the other side of the world. In contrast to communication by telephone, e-mail does not need the attention of both parties at the same time.

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Needs of E-mail

E-mail has become an indispensable part for the people who are living away or who has someone far away. People use e-mail for different reasons. In general, the reasons are the following:

(i) An email is delivered extremely fast as compared to the traditional post provided the e-mail address is correct.

(ii) It delivers time-stamped proof of an interaction. Apart from this, many e-mail services (like the Gmail) assemble the conversation on the same subject into single threads.

(iii) It is more secure and economical in comparison with other modes of communication.

(iv) It allows easy referencing. Messages sent or delivered can be easily stored. A majority of the e-mail services offer search facility through emails. It is comparatively easier to search old e-mail messages than old papers or documents.

(v) An e-mail can be amended and rephrased as much as it is needed before sending to the recipient(s).

(vi) It is easy to send the same piece of information to a number of recipients all at once like circulation of memos, agendas, and minutes, or distribute educational material.

E-mail address

An e-mail address is a unique address, which recognizes a location to send and receive email. The e-mail address comprises username, followed by a @ symbol, and then domain name i.e. username@domainname e.g. xyz@gmail.com. An e-mail address starts with a user name (xyz in this case) that refers to the recipient's mailbox. Then, sign @ followed by the host name (gmail.com in this case), also known as domain name.

11.7.3 Wi-Fi

Wi-Fi stands for 'Wireless Fidelity'. It is a popular wireless networking technology. In 1971, ALOHAnet connected the Great Hawaiian Islands with a UHF wireless packet network. However, Wi-Fi was invented in 1991 in Netherlands by NCR Corporation/AT&T. We can exchange information between two or more devices by using this technology. It allows local area networks to operate without using wire and cable. Wi-Fi has been developed for mobile computing devices, like laptops, but it is now extensively used for mobile applications and consumer electronics like televisions, DVD players, and digital cameras. It utilizes radio waves to form a secure, reliable and fast Wireless Local Area Network (WLAN). The devices need a wireless adapter to connect to the WLAN using Wi-Fi. It is extensively used to share an Internet connection among the devices connected to the WLAN.

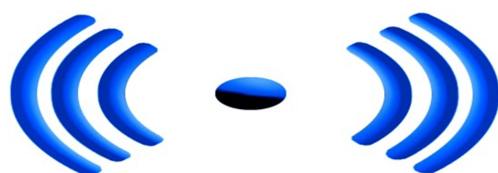


***Fig 11.7** Wi-Fi Logo*

Source: https://commons.wikimedia.org/wiki/File:Wifi_logo.jpg

Working principle of Wi-Fi technology

Wi-Fi works on the similar principle as other wireless devices. It operates through three vital elements—radio signals, antenna and router. The radio waves are keys that render Wi-Fi networking possible. The computers and cell phones have Wi-Fi cards. Wi-Fi compatibility has been using a new creation to constituent within the ground connected with the community network.

The real broadcast is connected in sequence. Actually, it is completed by means of stereo system surf and wires with the monitor to classification prone. Wi-Fi permits the person to get access to the web at any place in the actually provided area. A system can be generated within campuses of schools and colleges, resorts, library, personal institutes and espresso stores as well as on the open public spot to help to make the company much more lucrative and interact with their own customer whenever they want.

The radio signals are communicated via antennas and routers so that signals are picked up by Wi-Fi receivers, like computers and cell phones that are ready with Wi-Fi cards. Whenever, the computer receives the signals within the range of 100-150 feet for the router it connects the device instantaneously.

The range of the Wi-Fi depends upon the environment, indoor or outdoor ranges. The Wi-Fi cards read the signals and create an Internet connection between the user and the network. The speed of the device using Wi-Fi connection enhances as the computer gets closer to the main source and the speed is decreased as the computer gets further away.

Nowadays, laptops and mobile phones have inbuilt Wi-Fi cards. If it is a free type of network connection the user will be prompted with a login id and password. The free base network connection also function well in some areas. The Wi-Fi network connection creates hot spots in the cities. The hot spots are a connection point of the Wi-Fi network. It is a small box that is hardwired with the Internet. There are many Wi-Fi hot spots available in public places like restaurants, airports, and hotels offices, universities, etc.

The following are the advantages of Wi-Fi:

(i) It can be utilized to connect to the Internet anywhere and anytime and is quickly replacing the wired medium.

(ii) It is somewhat cheaper in comparison with the wired medium.

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(iii) Multiple devices can be connected with Wi-Fi to create a WLAN.

The limitations of Wi-Fi are the following:

(i) It consumes a lot of power.

(ii) Its speed is less than wired medium.

(iii) Transmission pauses or slows down when there is noise interference.

Check Your Progress

11. Who invented the Internet?
12. State one use of the Internet.
13. What are the features of an e-mail?
14. What is an e-mail address?
15. What does Wi-Fi stand for?
16. When and where was the Wi-Fi invented?

11.8 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. India tested a hydrogen bomb in the year 1998.
2. The first hydrogen bomb was tested at Eniwetok atoll on 1 November 1952 by Edward Teller, Stanislaw M. Ulam, and other US scientists.
3. Hertz is the unit used to measure radio frequencies.
4. Guglielmo Marconi patented his invention in the year 1896. Guglielmo Marconi designed a device capable of ringing a bell from 30 feet away.
5. Robert Watson-Watt, a Scottish scientist, developed a Radar system in 1935.
6. Radars are widely used in military operations. They are used in naval, ground as well as air defence purposes. Militaries rely on Radar to find and track their targets.
7. In 1936, the British Broadcasting Corporation (BBC) started regular high-definition public broadcasts in London.
8. It was in 1928 that Baird made the first overseas broadcast from London to New York and demonstrated the first colour television.
9. A computer together with hardware and software is called a computer system. A computer system consists of a Central Processing Unit (CPU), memory, input/output devices and storage devices.

10. Computers are of immense utility in our daily lives. Two applications of computers are as follows:
    (i) Computers are extensively being utilized in photography, dance, arts and culture. The fluid movement of dance can be shown live by means of animation. Photos can be digitized using computers.
    (ii) In various government departments, computers are used in the processing of data, maintaining a database of citizens and supporting a paperless environment.
11. The Internet was invented by Vinton G. Cerf and Robert E. Kahn in 1974.
12. Numerous programs called the search engines are available to search for information on any topic. Goggle Chrome, Mozilla, Bing, Wikipedia, Webopedia, Yahoo etc., are some of the popular search engines. The search is done by typing the question or query for which we are seeking answers or information.
13. It is a quick and more secure method of communication than the traditional methods. Less physical effort is needed to edit and send a letter of communication. Once the hardware, software, and Internet connection are ready, e-mail on the Internet is free, even if message is to be sent to the other side of the world.
14. An email address is a unique address, which recognizes a location to send and receive email. The email address comprises username, followed by a @ symbol, and then domain name i.e. username@domainname e.g. xyz@gmail.com. An email address starts with a user name (xyz in this case) that refers to the recipient's mailbox. Then, sign @ followed by the host name (gmail.com in this case), also known as domain name.
15. Wi-Fi stands for 'Wireless Fidelity'. It is a popular wireless networking technology.
16. Wi-Fi was invented in 1991 in Netherlands by NCR Corporation/AT&T.

11.9 SUMMARY

- A *hydrogen bomb* is a kind of *nuclear bomb*, just like an *atomic* bomb, where the explosive *energy* comes from *nuclear fusion*.
- The first hydrogen bomb was tested at Eniwetok atoll on 1 November 1952 by Edward Teller, Stanislaw M. Ulam, and other US scientists.
- Radio is a field of technology that deals with the transmission of information over distances by means of radio waves.

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- In November 1886, German physicist Heinrich Hertz became the first person to transmit and receive controlled radio waves. In 1894, Italian inventor and businessman Guglielmo Marconi designed a device capable of ringing a bell from 30 feet away.
- The full form of Radar is Radio Detection and Ranging. It is a system that provides microwave segment or ultra-high frequency of the radio spectrum to identify obstacles to control the area of the spot or range of an object.
- Robert Watson-Watt, a Scottish scientist, developed the Radar system in 1935. It was used to help protect Britain from air attacks. A Radar system is made up of a transmitter, a display, an antenna and a receiver.
- Television is a system for transmitting visual images and sounds that are reproduced on screens, essentially used to broadcast programmes for entertainment, education and information.
- In 1926, a Scottish inventor, John Logie Baird, gave the first public demonstration of a true television system in London.
- A computer is a device that accepts data as input, processes that data using programs, and outputs the processed data as information.
- In 1822, the Father of Computers, Charles Babbage started developing the first mechanical computer. Computers play a significant role in every field of life. They are used in homes, schools, colleges, research organizations, business, medical field, government offices, entertainment, etc.
- The Internet is a system of interconnected computer networks that utilizes the Internet protocol suite (TCP/IP) to communicate between networks and devices. It is a network of networks which makes it possible to communicate and interact with each other.
- The Internet was invented by Vinton G. Cerf and Robert E. Kahn in 1974. The Internet has become an integral part of our lives. It is extensively used for a wide variety of purposes.
- The Electronic Mail or E-mail is the transmission of text-based messages from one computer user to one or more recipients by means of a network.
- It is the most popular and quickest method of transmitting the messages. Ray Tomlinson is generally credited as the creator of e-mail.
- Wi-Fi stands for 'Wireless Fidelity'. It is a popular wireless networking technology. Wi-Fi was invented in 1991 in Netherlands by NCR Corporation/AT&T. It operates three vital elements—radio signals, antenna, and router.

11.10 KEY WORDS

- **Electromagnetic Waves:** These are the waves which are created as a result of vibrations between an electric field and a magnetic field.
- **Frequency Modulation:** It is the encoding of information in a carrier wave by varying the instantaneous frequency of the wave.
- **Iconoscope:** It was the first practical video camera tube to be used in early television cameras.
- **Isotopes:** They are atoms of the same element that have different numbers of neutrons but the same number of protons and electrons.
- **Router:** It is a networking device that forwards data packets between computer networks.

11.11 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Write a note on the invention of the hydrogen bomb.
2. Give a brief account of the invention of radio.
3. Write a note on the benefits and limitations of Radar.
4. Write short notes on the following:
   (a) E-Commerce (b) E-mail Address

Long-Answer Questions

1. What is Radar? Discuss the working principles and applications of Radar.
2. Analyse the history of television.
3. What is the Internet? What are its uses?
4. What is Wi-Fi technology? Discuss its working principle.
5. Discuss the use of computers.
6. Explain the features and needs of an E-mail.

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UNIT 12 PROGRESS OF SCIENCE AND TECHNOLOGY IN MODERN INDIA

Structure

12.0 INTRODUCTION

Before studying about the progress of science and technology in modern India, it is pertinent to understand the meaning of the terms science and technology. Science may be defined as any systematic activity that seeks to gain knowledge about the physical world. The activity which strives to put this knowledge to productive use is called technology. Thus, science and technology are closely interlinked in the present day world. The role of science and technology in national development has been duly recognized by the Government of India. The Second Five Year Plan (1956-61) stressed that 'the most important single factor in promoting economic development is the community's readiness to apply modem science and technology'. Pt. Jawaharlal Nehru initiated reforms to promote science and technology in India. The Government of India established the Department of Science and Technology (DST) in 1971with the objective of promoting new areas of science and technology. Similarly, at the State level, State Councils of Science and Technology were also established. As part of the national policy, the government is promoting a number of research and development schemes to boost scientific activities.

There has been considerable growth in the field of science and technology in modern India. There have been significant achievements in the field of astronomy, space science and atomic energy. The Ministry of Defence, Government of India established the Defence Research and Development Organisation (DRDO) with the purpose of empowering India with pioneering defence technologies and systems.

12.1 OBJECTIVES

After going through this unit, you will be able to:

- Learn about the progress of Modern India in the field of astronomy
- Discuss the development of Space Research in India
- Prepare an account of Atomic Energy Commission of India
- Explain the origin, growth and development of DRDO

12.2 PROGRESS IN ASTRONOMY

Kochhar believes that at critical stages in its history, astronomy got impetus for its ability to efficiently convey human fear of natural forces. Whenever cultural areas felt confident, they advanced astronomy. In earlier times, society provided backing to astronomy for calendric and astrological reasons. Since ancient man felt insecure on Earth, he felt scared of the Gods also. As astronomical knowledge increased, astrology also became more complicated. Belief in astrology thus, kept astronomy alive.

In the past, astronomical knowledge was not treated as scientific deduction, but as a divine revelation. How a purely scientific work was slowly made extra-scientific was exemplified by the reaction of Bhaskara-I who was a disciple of Aryabhatta. In India, a notable feature of pre-telescopic astronomical activity was its interaction with the work abroad. The Zij period had begun in Baghdad with the translation of Sanskrit texts. It came to a close at Delhi and Jaipur with the translation of Ulugh Beg's tables into Sanskrit.

In the early 18th century, the Maharaja of Jaipur, Sawai Jai Singh II of Amber, invited a number of European Jesuit astronomers and cartographers to one of his Yantra Mandir observatories, who had bought back the astronomical tables prepared by Philippe de La Hire in 1702. After examining La Hire's work, Sawai Jai Singh concluded that the observational techniques and instruments used in European astronomy were inferior to those used in India at that time. However, he did employ the use of telescopes. In his book titled *Zij-i-Muhammad Shahi*, he stated: 'telescopes were constructed in my kingdom and using them a number of observations were carried out'.

It is noteworthy that the year of arrival of the first British merchant ship coincided with the invention of telescope in Netherlands. The requirements of the maritime trade acted as a great incentive for growth of modern astronomy. Observatories were established at Paris and Greenwich to solve the problem of the longitude at sea, and many young men seeking employment with the English East India Company took tuition from the Astronomer Royal. In India, modern astronomy came with the arrival of Europeans.

Subsequent of the arrival of the English East India Company in India, the Hindu and Islamic traditions were slowly displaced by European astronomy, though there were attempts at harmonizing these traditions. The Indian scholar Mir Muhammad Hussain went to England in 1774 to study Western science and. After his return to India in 1777, he wrote a Persian treatise on astronomy. He described the heliocentric model, and argued that there exist an infinite number of universes (*awalim*), each with their own planets and stars, and that this demonstrates the omnipotence of God, who is not restricted to a single universe. Hussain's views about the universe bear a resemblance to the modern concept of a galaxy. His view coordinate with the modern view that the universe comprises billions of galaxies, each one having billions of stars. The last known *Zij* treatise was the *Zij-i Bahadurkhani*, written in 1838 by the Indian astronomer Ghulam Hussain Jaunpuri and published in 1855, dedicated to Bahadur Khan. The treatise incorporated the heliocentric system into the *Zij* tradition.

Modern astronomy in India was institutionalized more than 200 years ago by the English East India Company with the establishment of Madras Observatory in 1790 for assistance in navigational and geographical surveys. In 1899, it was replaced by a Solar Observatory at Kodaikanal established by the government to meet the demands of European scientists for sunny skies and in the hope that the study of the Sun would aid in the prediction of failure of monsoons, the key factor then in the Indian economy.

In India, the early use of telescopic astronomy was unfocussed, sporadic and often motivated by personal curiosity. In the 19th century, there was extensive use of science by the British to promote their commercial and political interests. Indians came into contact with modern science, when they were dispensing the role of providing cheap labour. Once introduced to modern science, Indians finally endeavoured to become full-fledged members of the international republic of science in their own right.

12.2.1 Space Research

India has a long tradition of space research including space science and technology. The first Indian satellite was named Aryabhata after the famous Indian mathematician-cum-astronomer, forging the link between modern India and its magnificent past when astronomy and mathematics were used to determine the position of the stars, and to construct platforms for lighting the flies for the welfare of the society.

An important chapter in India's space research was initiated between 1780 and 1790 when the Nungambakkam Observatory in Madras started a new phase of study in the field of climatology related to meteorology, weather prediction and allied subjects. The Madras Astronomical Observatory commenced studies in the fields of astronomy, geography and navigation in India by systematic meteorological observations in 1796. In 1823. the Colaba Observatory in Bombay was established

for astronomical and magnetic studies. In 1835 the Survey of India in Calcutta started contributing to the knowledge of geophysical phenomena. In 1836, the opening of the Trivandrum Observatory extended the scope for astronomical and meteorological studies.

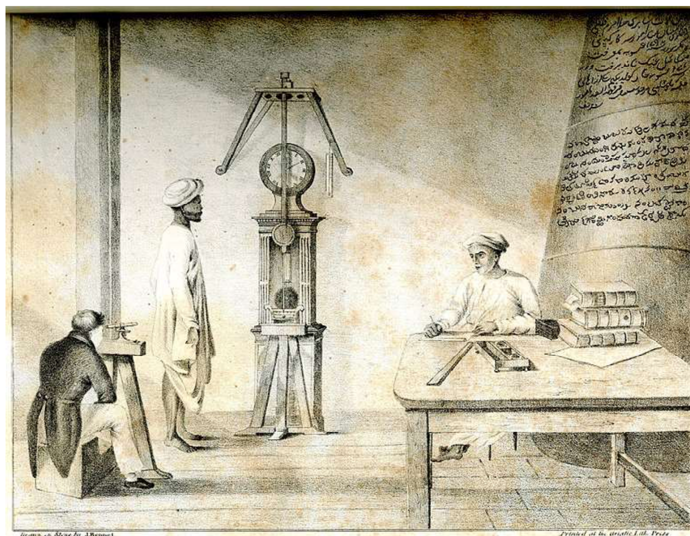


Fig 12.1 *Madras Observatory*

Source: https://commons.wikimedia.org/wiki File:Madras_Observatory_inside.jpg

In 1841, geomagnetic studies started in Shimla. An additional observatory was established in 1852 at Agasthyamalai near Trivandrum which enabled the study of the effect of altitude on magnetic and meteorological elements. The establishment of Agra observatory in 1862 and the Nagpur observatory in 1869 broadened the scope of studies of meteorological-cum-climatological subjects in India. The Indian Meteorological Department (IMD) in 1875 assumed the responsibility of managing the meteorological studies reported from various centres. At Kodaikanal, a Solar Physical Observatory was established in 1899 to promote the study of astrophysics.

In 1902, the Survey of India commenced systematic field observations for preparing terrestrial magnetic charts of India. In 1925, when Calcutta University founded a wireless laboratory, the scientific studies on the mutual interaction of radio waves and the upper atmosphere commenced. In 1932-33, India took part in the radio research programme of the Second International Polar Year. Ionospheric studies were started in 1933 at Bangalore and in 1934 at Allahabad. In 1940, an experimental unit was established in Bangalore as a part of the Indian Institute of Science. This study of cosmic rays comprised the nucleus of the work around which the Tata Institute of Fundamental Research (TIFR) was started in Bombay. In 1942, a Radio Research Committee was created with the objective of upper atmosphere studies. Research in the areas of cosmic rays also extended at various centres in India, especially at Bose Institute, Calcutta and Aligarh Muslim University.

The Physical Research Laboratory (PRL) was set-up at Ahmedabad, which specialized in the field of cosmic rays and astronomy and played a prominent role in forming the cradle of space research in India.

During the 1950s, considerable progress was made in the field of cosmic rays research mainly at the centres located at Waltair, Varanasi, Ahmedabad and Calcutta. As a result of research at these centres, India enjoyed a commendable position in the field of upper atmosphere research in the world. The Radio Research Committee of the Council of Scientific and Industrial Research (CSIR) started publishing a coordinated monthly bulletin, *Ionospheric Data*, in 1955, giving statistics of six Indian stations. The Radio Propagation Unit was established in 1956 at the National Physical Laboratory (NPL). It commenced experimental work for studies of atmospheric along with cosmic radio noise.

Manali Kallat Vainu Bappu was an Indian astronomer and president of the International Astronomical Union. He was responsible for setting up of a number of astronomical institutions in India. He established the Vainu Bappu Observatory named after him. He also contributed to the establishment of modern Indian Institute of Astrophysics. In collaboration with the American astronomer Olin Chaddock Wilson, he discovered the Wilson-Bappu Effect in 1957. He is regarded as the father of Modern Astronomy in India.



Fig 12.2 *Manali Vainu Bappu*

Source: https://en.wikipedia.org/wiki/Vainu_Bappu#/media/File:Vbappu.jpg

TIFR successfully flew the first constant altitude plastic balloon made in India in 1958. India participated in the world-wide space research activities of the International Geophysical Congress Council in 1959. The starting of 1960 was marked by several features in the further expansion of the field of Indian space research. The Department of Physics of the University of Delhi began research in 1960 on the ionosphere which produced valuable information on the ionospheric parameters and internal gravity waves. The first high altitude cosmic ray experiment with the Indian balloon was successfully launched from Hyderabad.

The Government of India participated in the efforts of the international community for the exploration of outer space for peaceful purposes in 1961. This

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year also witnessed the setting up of the Real Time Satellite Telemetry station at PRL, Ahmedabad. The Indian Space Programme began in 1962 with the creation of Indian National Committee for Space Research (INCOSPAR) with its headquarters at PRL, Ahmedabad.

INCOSPAR commenced work towards the setting up of an equatorial sounding rocket launching facility at Thumba, Trivandrum. An agreement was signed between DAE and NASA which provided for training of Indian scientists and engineers in the field of sounding rocket launching, as well as ground support, at the launching station at Wallops Island and the Goddard Space Flight Centre, USA. Thus, a new era ushered in India's space research from both national and international considerations.

Thumba Equatorial Rocket Launching Station (TERLS) initiated the first sounding rocket programme in 1963. A team of scientists from United Nations visited TERLS in 1964 in order to widen the scope of space research activities in India for collaboration with the world body. In the same year, an agreement of collaboration was signed with CNES, France, for transfer of knowledge to manufacture rockets in India. The Atomic Energy Commission approved the establishment of the Space Science and Technology Centre (SSTC) at Trivandrum for developing rockets of Indian design.

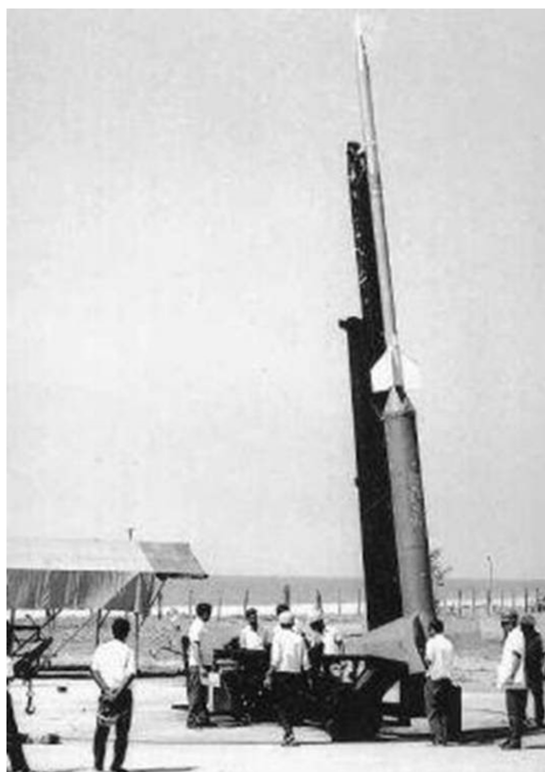


Fig 12.3 *First Rocket Launched from TERLS*

Source:https://commons.wikimedia.org/wiki/Category:Thumba_Equatorial_Rocket_Launching_Station#/media/File:TERLS-01.jpg

There was tremendous growth of space research activities during the years between 1965 and 1975. In 1965-66, TERLS launched a number of sounding rocket launchings. The first International Training Course for Satellite Communication Technology was organized at ESCES, Ahmedabad, and T. V link tests with Japan and Australia were conducted successfully. The first Indian rocket was developed at SSTC and named Rohini-75. It was successfully launched from Thumba in 1967.

In 1968, an eventful period in the history of space research in India started when the Prime Minister dedicated TERLS as UN-sponsored International Range. In 1969, INCOSPAR was reconstituted under the national body affiliated to COSPAR, viz. Indian National Science Academy (INSA), and it continued to have relations with COSPAR. The Indian Space Research Organization (ISRO) was set-up in 1969 and was entrusted with the programme of space research and its utilization for peaceful purposes with its headquarters at Ahmedabad. The ISRO and the Physical Research Laboratory (PRL) functioned as autonomous agencies supported mainly by the Department of Energy (DAE). Later these organizations were brought within the ambit of the Space Commission and the Department of Space (DOS) was created in 1972.

Objectives of ISRO

The principal objectives of ISRO are the following:

(i) Application of space science and technology to promote national goals in mass communication and education by means of satellites and the survey and management of natural resources through remote sensing technology from space platforms;

(ii) Development of space technology in India with self-reliance to further the above-mentioned applications in the matter of design, development, and manufacture of satellites and rocket systems with their related tests and operational facilities; and

(iii) Utilization of the by-products from developments in space research in other fields of research, industry, education, and related fields. ISRO, thus, aimed at harnessing developments in space science and technology for the social and economic progress of the country.

The activities of ISRO are performed at its four space centres, namely, (i) Vikram Sarabhai Space Centre (VSSC) at Trivandrum, Kerala; (ii) Space Applications Centre (SAC) at Ahmedabad, Gujarat; (iii) ISRO Satellite Centre (ISAG) at Bangalore, Karnataka; and (iv) SHAR Centre at Sriharikota, Andhra Pradesh.

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12.3 ATOMIC ENERGY COMMISSION

For the overall development of any nation, an adequate and uninterrupted power generation is an inherent necessity. With the coal deposits depleting and the limited potential of hydel power, the nation's future requirements of power can be met by tapping nuclear and other non-conventional energy resources. The non-conventional sources of energy are appropriate for small-decentralized applications, while nuclear power stations are suitable for the large Central Generating Stations. In the quest of the peaceful uses of atomic energy, power generation based on nuclear energy assumes first and foremost place and India has achieved a number of milestones in this field. India is the only developing country, which has achieved self-reliance in the field of nuclear fuel cycle activities, amidst a number of international technology control regimes.

After India attained independence in 1947, the Atomic Energy Bill was passed by the Parliament in 1948. The Indian Atomic Energy Commission (AEC) was first established on 10 August 1948 in the Department of Scientific Research, which was created in June 1948. Dr.Homi J.Bhabha was the first chairman of the commission. The Department of Atomic Energy (DAE) was set-up on 3 August 1954 under the direct charge of the Prime Minister of India through a Presidential Order. Afterwards, in accordance with a Government Resolution dated 1 March 1958, the Atomic Energy Commission was established in the Department of Atomic Energy. On 24 March 1958, Pt. Jawaharlal Nehru, the then Prime Minister of India, also laid a copy of this Resolution on the table of the Lok Sabha.

As per the Resolution constituting the AEC, the Secretary to the Government of India in the Department of Atomic Energy is the ex-officio Chairman of the Commission. The other Members of the AEC are appointed for each calendar year on the recommendations of the Chairman, AEC and after approval by the Prime Minster. The commission was assigned the job of formulation and implementation of the policy of the government in all matters concerning atomic energy.

Vision

The vision of the commission was to empower India by means of technology, creation of more wealth and providing better quality of life to its citizens. This goal was to be realized by making India energy independent, contributing to provision of adequate, safe and nutritious food and better health care to the Indians through development and deployment of nuclear and radiation technologies and their applications.

12.3.1 Functions of the Atomic Energy Commission

(i) To conduct research work associated with atomic science in India.

(ii) To train the atomic scientists.

(iii) To encourage nuclear research in the laboratories of the Commission.

(iv) To explore for atomic minerals in India and extract minerals so that they can be used in the industries.

There are five research centres of the Atomic Energy Commission. These are as follows:

(i) Bhabha Atomic Research Centre (BARC), Mumbai

(ii) Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam (Tamil Nadu)

(iii) Raja Ramanna Centre for Advanced Technology (RRCAT), Indore

(iv) Variable Energy Cyclotron Centre (VECC), Kolkata

(v) Atomic Minerals Directorate for Exploration and Research (AMD), Hyderabad.

AEC also provides financial assistance to various autonomous national institutions which are involved in research in the field and has several organizations under it.

12.4 DRDO

After India attained Independence, the Government of India established the Defence Science Organization in 1948 to advise and assist the defence services on scientific problems and to conduct research in areas associated with defence. In 1958, the Defence Research and Development Organization (DRDO) was set-up by integrating the units of Defence Science Organization with some of the technical development establishments. Subsequently, a separate Department of Defence Research & Development was established in 1980 for improving administrative efficiency.

The Department frames and conducts programmes of scientific research, design and development in the areas of relevance to national security leading to the induction of new weapons, platforms and other equipment required by the Armed Forces. It functions under the control of Scientific Advisor to the Defence Minister.

The Department aims at attaining technological self-reliance in defence systems and weapons. To accomplish this, the Department is empowered to design, develop and lead on to production of the state-of-the-art weapon systems, sensors,

platforms and allied equipment to meet the requirements of the Armed Forces and to provide assistance in the field of military sciences to improve war efficiency of the troops. The Department conducts various research and development programmes and projects through a network of 49 laboratories of the DRDO located all over India and a Centre for Military Airworthiness and Certification (CEMILAC). It also administers the Aeronautical Development Agency (ADA) which is engaged in design and development of the Light Combat Aircraft (LCA). These laboratories and establishments conducts programmes and projects in varied fields of aeronautics, missiles, combat vehicles, armaments, electronics and instrumentation, advanced computing and networking, engineering systems, advanced materials and composites, agriculture and life sciences, and naval research and development. To realize its goals, DRDO has a strong partnership with a number of academic institutions, agencies, PSUs and private sector enterprises.

DRDO was chiefly involved in activities related to clothing, ballistics, operations research, and general stores between 1948 and 1957. During the next decade 1958-68, several products, including small and medium weapon systems, explosives, communication systems and code machines were developed. In the 1960s, DRDO started Project Indigo which was its first major project in surface-to-air missiles (SAM). However, it was discontinued in later years without achieving full success. Project Indigo led to Project Devil, along with Project Valiant, to develop short-range SAM and ICBM in the 1970s. The significant measures to make DRDO effective in its functioning comprise the establishment of a Defence Technology Commission. The programmes which were chiefly managed by DRDO have seen substantial success with many of the systems witnessing speedy deployment along with yielding significant technological benefits.

DRDO addressed major hardware systems which comprised field guns, radar, sonar systems, communication equipment and aeronautical systems between 1969 and 1979. During the decade 1980-90, it carried out multi-disciplinary programmes for the development of complex and sophisticated weapon systems having latest technology. Between the years 1990 and 2000, some major high technology projects included Ballistic Tank (MBT) Arjun, missiles Prithvi and Agni, pilotless target aircraft Lakshya etc. DRDO has achieved technological self-reliance in ammunition, armored systems, surface-to-surface missiles, sonar systems, Electronic Warfare (EW) systems and advanced computing.

DRDO conducts specialized training at its two foremost training institutions called Institute of Armament Technology, Pune and Defence Institute of Work Study, Mussoorie. At these institutions the courses have been evolved chiefly to meet the requirements of DRDO, Department of Defence Production and Supplies and the three Services.

Check Your Progress

7. What is the full form of DRDO?
8. Name the project started by DRDO in the 1960s.

12.5 ANSWERS TO CHECK YOUR PROGRESS

1. The English East India Company with the establishment of Madras Observatory in 1790 for assistance in navigational and geographical surveys.
2. Mir Muhammad Hussain was the Indian astronomer who travelled to England in 1774 to study Western science.
3. The INCOSPAR was established in 1962.
4. ISRO stands for the Indian Space Research Organization. It was established in 1969.
5. The Indian Atomic Energy Commission (AEC) was first established on 10 August 1948. Dr.Homi J.Bhabha was the first chairman of the commission.
6. The main functions of the Atomic Energy Commission are the following:
   (i) To conduct research work associated with atomic science in India.
   (ii) To train the atomic scientists.
   (iii) To encourage nuclear research in the laboratories of the Commission.
   (iv) To explore for atomic minerals in India and extract minerals so that they can be used in the industries.
7. DRDO stands for Defence Research and Development Organization.
8. Project Indigo was the project started by DRDO in the 1960s.

12.6 SUMMARY

- In earlier times, society provided backing for astronomy for calendric and astrological reasons. As astronomical knowledge increased, astrology also became more complicated. Astronomical knowledge was not treated as scientific deduction, but as a divine revelation.
- In the early 18th century, the Maharaja of Jaipur, Sawai Jai Singh II of Amber, invited European Jesuit astronomers and cartographers to one of his Yantra Mandir observatories

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- In India modern astronomy came with the arrival of Europeans. The requirements of the maritime trade acted as a great incentive for growth of modern astronomy.
- Indian scholar Mir Muhammad Hussain described the heliocentric model. His views about the universe bear a resemblance to the modern concept of galaxy.
- Modern astronomy in India was institutionalized more than 200 years ago by the English East India Company with the establishment of Madras Observatory in 1790.
- India has a long tradition of space research including space science and technology. In the modern times, a number of observatories were established at various places like Madras, Bombay etc., in India for the study of astronomy and other related fields.
- Manali Kallat Vainu Bappu was an Indian astronomer who was responsible for the establishment of several astronomical institutions in India. He discovered the Wilson-Bappu Effect in 1957. He is considered as the Father of Modern Astronomy in India.
- The Indian Space Programme began in 1962 with the creation of Indian National Committee for Space Research (INCOSPAR) with its headquarters at PRL, Ahmedabad
- The Indian Space Research Organization (ISRO) was set-up in 1969 and was entrusted with the programme of space research and its utilization for peaceful purposes with its headquarters at Ahmedabad.
- The Indian Atomic Energy Commission (AEC) was first established on 10 August 1948 in the Department of Scientific Research, which was created in June 1948. Dr. Homi J.Bhabha was the first chairman of the commission. The Department of Atomic Energy (DAE) was set-up on 3 August 1954.
- The vision of the AEC is to empower India by means of technology, creation of more wealth and providing better quality of life to its citizen. Italso provides financial assistance to various autonomous national institutions which are involved in research in the field and has several organizations under it.
- The Government of India established the Defence research and Development Organization in 1958. It frames and conducts programmes of scientific research, design and development in the areas of relevance to national security leading to the induction of new weapons, platforms and other equipment required by the Armed Forces.

- The Department aims at attaining technological self-reliance in defence systems and weapons. In the 1960s DRDO started Project Indigo which was its first major project in surface-to-air missiles (SAM).
- DRDO conducts specialized training at its two foremost training institutions called Institute of Armament Technology, Pune and Defence Institute of Work Study, Mussoorie.

12.7 KEY WORDS

- **Aeronautics:** It is the science or art concerned with the study, design, and manufacturing of air flight-capable machines, and the techniques of operating aircraft and rockets within the atmosphere.
- **Astrology:** It is a pseudoscience that claims to divine information about human affairs and terrestrial events by studying the movements and relative positions of celestial objects.
- **Heliocentric Model:** It is the astronomical model in which the Earth and planets revolve around the Sun at the center of the Universe.
- **Observatory:** It is a room or building housing an astronomical telescope or other scientific equipment for the study of natural phenomena.
- **State-of-the-art:** It refers to the highest level of general development, as of a device, technique, or scientific field achieved at a particular time.

12.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What do you know about DRDO?
2. What were the factors responsible for the establishment of the Atomic Energy Commission of India?

Long-Answer Questions

1. Discuss the progress made by India in the field of astronomy in modern times.
2. Explain the evolution of space research in India.
3. Describe the establishment of ISRO with major emphasis on its objectives.

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BLOCK - V
PROGRESS OF SCIENCE AND TECHNOLOGY IN MODERN INDIA

UNIT 13 PIONEERS IN MODERN SCIENCE IN INDIA-I

Structure

13.0 INTRODUCTION

The introduction of Western science in India had two facets-the formal one that was half-heartedly attempted mainly by the British administration to fulfill their goals and the real one that was accomplished by the forward-looking pioneers who laid down a solid foundation for the progress of science even within the colonial restrictions. The development of scientific thought in modern India can be credited to the scientists of the 19th century. Jagdish Chandra Bose initiated the study of radio and microwave optics, and contributed significantly to plant physiology and laid the foundation of experimental science in the Indian subcontinent. Prafulla Chandra Ray was the pathfinder and originator of chemical research in modern India. Srinivasa Ramanujan was one of India's greatest mathematical geniuses. Nobel Laureate Chandrasekhara Venkata Raman brought about an unprecedented change in Indian scientific thinking. He is known for his pioneering work on scattering of light.

13.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the contribution of J.C Bose in the field of science in India
- Analyse the contribution of P.C Ray in the development of modern science

- Discuss the contribution of Srinivasa Ramanujan in the field of mathematics
- Examine the role of C.V Raman in the development of Physics and other sciences in Modern India

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13.1 J.C BOSE

Jagdish Chandra Bose was born on 30 November 1858 in a Bengali Kayastha family at Munsiganj in Mymensingh (now in Bangladesh) to Bhagwan Chandra Bose and Bama Sundari Bose. His father worked as a Deputy Magistrate and Assistant Commissioner in Faridpur, Bardhaman and some other places. He was also a leading member of the Brahmo Samaj.

Raised in accordance with the Indian traditions, his father wanted him to learn Bengali before he learnt English. J.C. Bose got his early education in a vernacular school in his village. In 1869, he was admitted to the Hare School. He then enrolled at St. Xavier School, Calcutta where Jesuit priest Father Eugene Lafont helped him develop interest in natural sciences. When he was young, he read the Bengali translation of the Ramayana and the Mahabharata and was profoundly impressed with the stories of heroism and sacrifice described in these two great epics. Besides studies, he participated in boxing and gymnastics. In his childhood, he was fond of collecting all kinds of insects, trapping fish and capturing even water snakes. As a student of St. Xavier's College, Calcutta, he used to spend all his spare cash on animal pets, and all his spare time on their care. In those times, the University of Calcutta did not offer Zoology. Instead, Physics was a popular subject. As a result, Bose took Physics. Father E. Lafont, Professor of Physics, instilled in him a love for physics, and this was further nurtured under Lord Raleigh's influence.

J.C. Bose obtained his B.A. degree from University of Calcutta in 1879. In 1881, he went to England to study medicine at the University of London. He obtained the Natural Science Tripos of Cambridge University and B.Sc. of London University. In 1885, Bose returned to India and joined the Presidency College, Calcutta, as a Professor of Physics. He faced racism in his job. The salary offered to him was humiliatingly lower than his British counterparts and the research facilities were inadequate. In spite of this, he was determined to struggle for scientific achievement. He protested by teaching without salary for three years.

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Fig 13.1 *Jagdish Chandra Bose*

Source: https://commons.wikimedia.org/wiki/File:Jagadish_Chandra_Bose_1926.jpg

Jagdish Chandra Bose became famous for his experiments in Physics on electric waves. He initiated scientific research on electric waves in the early phase of the 19th century. He studied the nature of spark discharge from an induction coil and its effect on the surrounding medium. James Clarke Maxwell had mathematically predicted twenty years before that light waves are electromagnetic in nature. However, he died in 1879. His prediction was verified by Heinrich Hertz in 1880. In 1887, Hertz discovered that electrical discharges from a machine produce waves in space somewhat similar to light waves. The shortest electromagnetic wave obtained by Hertz was of wavelength 5 metres. Marconi, Lodge etc., also used electric waves of such large wavelengths. Bose devised his own instrument called Electric Radiator, and was successful in reducing waves to the millimeter level (about 5 millimetre wavelength). He realized the disadvantages of long waves for studying their light-like properties. He quantitatively advanced Hertz's study. Bose and Hertz demonstrated that short electromagnetic waves behave exactly as a beam of light, both being agreeable to reflection and refraction. Bose even managed to 'polarize' the electromagnetic waves. His other investigation was associated with the study of the rotation of the plane of polarization. He discovered a special crystal, 'nema-lite' and showed that it polarized electric waves just as a light-beam is polarized by tourmaline (a crystal). His first scientific publication entitled 'On Polarization of Electric Waves by Double Refracting Crystals' was published in the May 1895 issue of the Journal of the *Asiatic Society of Bengal*.

Bose clearly foresaw the application of the electric waves of his experiments to wireless telegraphy (telegraphy without wires). In 1895, he demonstrated before the Governor of Bengal and the public how electric waves could travel from his radiator in the lecture room to another 75 feet away, where his receiver managed to pick up enough energy to ring a bell and fire a pistol. He could repeat his experiment by the distance of one mile.

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On the invitation of the British Association, Professor Bose went to attend its Liverpool session to demonstrate his experiments. It was a grand success. Lord Kelvin was so impressed by Bose's experiments and papers that he broke into warmest praise for him. This success brought an invitation to deliver a series of Friday Evening Discourses at the Royal Institution. It made the India Office authorities, to appreciate the genius in J.C. Bose and they immediately granted him three month's extra deputation leave for preparation and delivery of the lectures.

Father Lafont mentioned that Bose's discovery of wireless preceded that of Marconi. However, Bose did not take any patent as he thought that result of any scientific discovery should be public property. On his ascetic trait, the leading British technical journal, *The Electric Engineer*, expressed surprise 'that no secret was at any time made as to its construction (signaling device), so that it has been left open to the entire world to adopt it for practical and possibly money-making purposes'. Sister Nivedita had profound influence on Bose. She supported him by organizing financial support and editing his manuscripts and made sure that Bose was able to continue with and share his work. She along with Mrs. Ole Bull took patents (for Bose's self recovering detector of electric rays) on his behalf in Britain and America, but Bose never used the rights and allowed the patents to lapse. J.C. Bose served the Calcutta University as Professor of Physics from 1885 to 1915. In 1896, he obtained the D.Sc. degree from University of London.

From 1899 to 1902, J.C. Bose noted the peculiar behaviour of his electric wave receiver or 'coherer' (radio signal detector). It showed signs of fatigue after continuous use, but could be 'revived' to its original sensitivity after some rest. Such instances, along with his inborn interest in biology, diverted him to the investigation of responses in the living and non-living to different kinds of external stimuli. At the International Congress in Physics at Paris in 1900 and later at the British Association for Advancement of Science, Bradford, he read a paper titled 'On the similarity in Responses in Inorganic and Living Matter'.

Bose performed a comparative study of the fatigue response of various metals and organic tissue in plants. His observations and use of words like 'fatigue', 'sleep', 'exaltation', 'rest', 'irritability' etc., in respect of inert and vegetative matter were criticized. He worked hard during 1899–1904. He published eight papers and completed a monograph: 'Response in the living and non-living'. He observed that the curve of the fatigue of an instrument closely bears resemblance to the fatigue curve of an animal tissue. Indeed, Bose thought that his new view, life pulsating in all matter from rocks and reefs to reeds and rams would integrate the fragmented sciences.

Bose's inclination towards life sciences and plant physiology in particular, was actually a revival of his old and innate interest in animal life. In fact, he studied medicine for some time in England. From 1907 to 1933, he studied the phenomenon of response as observed in the plant kingdom, and which in complexity was intermediate between animal and inorganic matter. His investigations showed that not only animals but also vegetable tissues under different kinds of external stimuli

(such as mechanical, application of heat, electric shock, and chemical) produce similar electric responses. He invented the 'crescograph' in which the undetectably slow growth of plant could be magnified several million times and accurately recorded. In 1914, Bose demonstrated his findings before the members of the British Royal Society. His 'resonant recorder' registered the speed of transmission of excitatory impulse; the 'oscillating recorder' traced the throbbing pulsations of the telegraph plant and finally the 'death-recorder' indicated the death-throes of the plant. Bose published a number of books such as, *The Physiology of Photosynthesis*, *The Motor Mechanism of Plants*, *The Nervous Mechanism of Plants*, etc. He was elected a Fellow of the Royal Society in 1920 in recognition for his outstanding work. His pioneering research activities and lecture tours in various countries brought not only unprecedented fame to him but also an era of glory to India. This has been beautifully narrated in several letters written by Swami Vivekananda and Tagore.

J.C Bose retired as Senior Professor of Physics in 1915 but continued to be associated with Presidency College as Emeritus Professor for two years. He also raised money from the public for establishing a research institution. On 30 November 1917 he inaugurated the new research institute which according to him was 'not merely a laboratory but a temple'. As a matter of fact, the institute came to be known as *Basu Vijnan Mandir*-a temple of science. In his dedicatory address at the inaugural ceremony of the institute, Bose said, 'the advancement of science is the principal object of the Institute, and also diffusion of know-ledge'. He then expressed the desire 'that so far as the limited accommodation permits, the facilities of the Institute should be available to workers from all countries. In this I am attempting to carry out the traditions of my country which, so far back as 25 centuries ago, welcomed all scholars from different parts of the world within the precincts of the ancient seats of learning of Nalanda and Taxila'.

Bose died of heart attack on 24 November 1937. In 1945, a biographical note on him appeared in the *Encyclopaedia Britannica*. It mentioned that his biophysical research was 'so much in advance of his time that its precise evaluation was not possible'.

Check Your Progress

1. What was the use of the 'crescograph' invented by J. C. Bose?
2. When was J. C. Bose elected to the Royal Society?

13.3 P.C RAY

Acharya Sir Prafulla Chandra Ray was born on 2 August 1861, in the village of Raruli-Katipara, then in the Jessore District of East Bengal. His father, Harish Chandra Raychowdhary, a Kayastha zamindar, was a man of high intellectual calibre. His mother Bhubanmohini Devi was the daughter of a local taluqdar. In

1866, P.C Ray began his education in the village school run by his father, and studied there until he was nine. He was admitted to Hare School in Calcutta in 1870. However, due to illness he could not pursue his studies for nearly six years. After recovering from illness, Ray was admitted to Albert School, Calcutta. He passed the Matriculation examination in 1878 and was admitted to Metropolitan Institution as FA (First Art) student. Though Ray primarily focused on history and literature, he saw in chemistry a potential source of producing materials and resources for human benefits. He also recognized that India's future would greatly depend on progress in science. He attended chemistry lectures as an external student at Presidency College. His interest in Chemistry can be attributed to the influence of Alexander Pedler, an inspiring lecturer and experimentalist, who was then Professor of Chemistry at the Presidency College. He passed his FA exam in 1881 and was admitted to the BA degree course of the University of Calcutta. In 1882, he won the Gilchrist Prize which enabled him to go to Edinburgh (UK) for higher studies.



Fig 13.2 *Prafulla Chandra Ray*

Source: https://commons.wikimedia.org/wiki/File:Young_P.C._Ray.jpg

At the University of Edinburgh, P.C. Ray received his B. Sc. degree in 1885 and D.Sc in 1887. The subject of his Doctoral dissertation was 'Conjugated sulphates of the Copper-Magnesium Group: A Study of Isomorphous Mixtures and Molecular Combinations'. Ray developed contacts with the famous chemists such as Marshall and Crum Brous at Edinburgh. He also wrote an essay entitled 'India: Before and After the Mutiny' in which he criticized the British rule in India.

On his return to India, Ray struggled hard to get a suitable job for a year. During this period, he received support and encouragement from J.C Bose. He joined Presidency College, Calcutta as Assistant Professor of Chemistry in 1889. He became an extremely inspiring teacher. He was lucid and lively in his exposition.

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The authorities of the Presidency College maintained that the institution was mainly for teaching and they believed that research would involve wastage of money and time. So the research facilities barely existed in the College. Sir Alexander Pedler, the then Principal of the College, gave ample encouragement to Ray and helped him to acquire useful equipment and chemicals. C.B. Bhaduri, Pedler's lecture assistant, also helped Ray considerably in performing scientific experiments. P.C. Ray retired as Professor of Chemistry from the Presidency College after 27 years of active service. Later, he became the Professor of Chemistry at the newly founded University College of Science. It is mainly because of his efforts that this institution received the initial stimuli to become one of the leading institutes of active chemical research in India.

P.C. Ray was a great researcher. He used the forum of the Asiatic Society, Calcutta, to communicate to the general public, the results of his scientific investigations. During the last two decades of nineteenth century, Indian leadership in science was in the hands of J.C. Bose and P.C. Ray. Both of them were enthusiastically connected with the Science Association of Mahendralal.

Ray conducted systematic chemical analysis of a number of rare Indian minerals in 1894 with the aim of discovering in them some of the missing elements of Mendeleeff's Periodic Table. Though the results were inconclusive, yet in the course of his analytical investigations, Ray noticed the formation of a stable compound, mercurous nitrite. This finding of the new compound (a yellow crystalline deposit) was reported to the *Journal of the Royal Asiatic Society* (1896).

After this publication, a continuous series of papers on nitrites were published in the *Journal of Chemical Society*, London. Ray and his pupil, N.R. Dhar published a paper on the vapor density of Ammonium nitrite. When this paper was presented before the London Chemical Society, Ramsay and Veley warmly congratulated the authors. Professor Armstrong commented to Ray: 'The way you have made yourself a master of nitrites is very interesting.'

In the University College of Science, Ray conducted a study of compounds of metallic elements with organic sulphur derivatives, and examined the formation and behaviours of some of their simple derivatives. A number of students conducted researches on double sulphates, chemical and physical properties of compounds of zinc, cadmium, mercury and so on under his able guidance. A group of young men established 'The Bengal Chemical and Pharmaceutical Works' on 12 April 1901 under his dynamic leadership. Many other industrial concerns such as ''The Calcutta Pottery Works,' and 'Bengal Enamel Works' were floated, mainly with Ray's inspiration and technical guidance. Ray, thus, became the founder of Indian Chemical School and leader of the Indian Chemical Industry. He is also called as the 'Father of Indian Chemistry'.

P.C Ray had a fascination for the history of science. He collected information from old Sanskrit literature relating to the pursuit of chemistry in ancient India and studied them thoroughly. By 1902, Ray had completed his monumental work,

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History of Hindu Chemistry. He received applause from Bertholet in his fifteen pages review in the *Journal des Savants* (January, 1903). Arrhenius and many other stalwarts in this field accepted the pioneering role of Indian Chemists in the ancient times. Referring to Ray's lecture in London delivered on 10 January 1916, 'Nature' commented in its March 23 issue:

> The lecture consists of a brief resume of original chemical research as carried out in Bengal in the last twenty years, and as an appendix a list of 126 papers. Some of these are of considerable value and interest, and indicate enthusiastic work on the part of this newly created school, which is mainly due to the example and work of Professor Ray himself.

P.C. Ray was knighted in 1919. He was elected General President of the Indian Science Congress 1920, and in 1924 was elected as the Founder-President of the Indian Chemical Society. In 1934, he was elected as Honorary Fellow of the Chemical Society (London) and of the *Deutsche Akademic* (Munich). Ray published 142 research papers and notes in scientific journals between 1897 and 1936,. He wrote his autobiography, *Life and Experiences of a Bengali Chemist*.

Ray believed in the ideology of *Swadeshi* and was admired by Mahatma Gandhi, Rabindranath Tagore and Jawaharlal Nehru. He created a trust from his own income which supported a high school and a number of other organizations. His life came to an end on 16 June 1944.

Check Your Progress

3. Who is known as the Father of Indian Chemistry?
4. When was P.C Ray knighted?

13.3 SRINIVASA RAMANUJAN

Srinivasa Ramanujan was an Indian mathematician who was born on 22 December 1887 into a Tamil Brahmin Iyengar family in Kumbakonam (Erode), Tamil Nadu. His father, Kuppuswamy Srinivasa Iyengar worked as a clerk in a sari shop and his mother Komalatammal was a housewife and sang at a local temple. He belonged to a poor but renowned family. Ramanujan showed prodigious talent with numbers, equations and geometrical problems even before he reached high school. He passed his matriculation examination in 1903. After this, the neglect of English resulted in his failure in the Intermediate examination. Consequently, the Subrahmanyam scholarship that he had won earlier was discontinued. He had to abandon his studies for he was too poor to afford university education without a scholarship. In 1907, he tried again but failed.

After his failure in the intermediate examination, Ramanujan tried hard to secure a job but in vain. His father got infuriated when he saw the son engrossed in mathematical problems all the time. He ridiculed Ramanujan for wasting time in

scribbling futile calculations and theories that in no way earned him a living. Fearing that the son might get mad in pursuing mathematics, he got Ramanujan married to Janaki in 1909. Ramanujan's friends realized his acute financial problems and got him a clerical job in the Madras Port Trust.

Ramanujan's employer Sir Francis Spring who was a mathematician of distinction himself, encouraged Ramanujan in his mathematical pursuits. He quietly sent some of the problems worked out by Ramanujan to Professor G.H. Hardy who was a renowned Cambridge mathematician. Prof. Hardy found Ramanujan's work of profound significance and straight away decided to get him to Cambridge University. Ramanujan's first full length research paper was entitled, 'On Some Properties of Bernoulli Number'. This was published in the Journal of the Indian Mathematical Society in 1911. In 1914, he arranged a scholarship for Ramanujan. With his help Ramanujan became an honoured student at Cambridge. His uncanny memory and his ability to solve complicated mathematical problems impressed everyone.



Fig 13.3 *Srinivasa Ramanujan*

Source: https://commons.wikimedia.org/wiki/File:Srinivasa_Ramanujan_-_OPC_-_1.jpg

Ramanujan was plagued by health problems throughout his life. His health worsened and did not allow him to stay at Cambridge for more than five years. But even in such a short period, he published 21 most exceptional papers of amazing originality. Vinogradow, Stalin Prize winner using methods observed mainly in the work of Ramanujan and his collaborators, has been able to demonstrate that every large integer can be expressed as the sum of at most four prime numbers. In 1917, Ramanujan gave a formula for the partition of any natural number by a series of successive approximations. The well-known Waring problem (expressing an integer as the sum of squares, cubes or higher powers of a few integers) remained unsolved for a century until Ramanujan and his collaborators invented the analytical

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method for solving the problem. The Royal Society went out of its way and made him a Fellow (FRS) in 1918. The same year, he was made a Fellow of the Trinity College, Cambridge University.

Ramanujan worked on Riemann's Zeta function, moch-theta function, modular equations, identities, theories of continued fractions and elliptic functions. He desired that his mathematical research would remain clean and pure from any contact with technological applications. In reality, the concept that science has a social function to perform had not arisen by that time. The work of Ramanujan's and that of other scientists on Riemann's Zeta function has now been used in technology. It has been applied to the investigation of the temperature of furnaces aimed at building blast furnaces.

Ramanujan's researches made him a mathematician of the highest order. Julian Huxley has adjudged him as the greatest mathematician of the century. Renowned mathematician J.R. Newman regarded the genius of Ramanujan as supreme. Prof. Hardy wrote, ' I still say to myself when I am depressed and find myself forced to listen to pompous and tiresome people, 'Well, I have done one thing, You could never have done and that is to have collaborated with both Littlewood and Ramanujan on something like equal terms.'

Overwork at Cambridge deteriorated Ramanujan's health. He was diagnosed with acute tuberculosis of lungs and severe vitamin deficiency. The doctor advised him to return to the warm climate of India. Prof. Hardy regretted this very much: 'I owe, more to Ramanujan than to anyone else in the world and any association with him is the one romantic incident of my life.' His return to Kumbakonam, India in 1919 brought no relief to him. Despite the best medical care, he died on 26 April 1920 at the age of 32. To India and the world, Ramanujan left his notebooks in which he jotted down his calculations and theorems-a mine of mathematical knowledge for generations to come. They are called Ramanujan's Frayed Notebooks. His brother Tirunarayanan compiled Ramanujan's remaining handwritten notes, consisting of formulae on singular moduli, hyper geometric series and continued fractions.

Check Your Progress

5. In which field did Ramanujan excel?
6. Which work of Srinivasa Ramanujan was published in the Journal of Indian Mathematical Society?

13.4 C.V RAMAN

Nobel Laureate Chandrasekhar Venkat Raman, popularly known as C.V Raman, was an Indian physicist who was born on 7 November 1888, at Tiruchirapalli, Madras Presidency (now Trichy, Tamil Nadu). He belonged to a Hindu Brahmin

family. His father Chandrasekhar Aiyar was a teacher at the local high school. His family shifted to Vishakhapatnam in Andhra Pradesh as his father was appointed as a Professor of Physics at Mrs A.V. Narasimha Rao College. Here he got admission in St. Aloysius' Anglo-Indian High School. He passed his matriculation examination at the age of 11. C.V Raman was a born genius. At the age of 12, he passed the entrance examination of Madras University with distinction.



Fig 13.4 *Chandrasekhar Venkat Raman*

Source:https://commons.wikimedia.org/wiki/Category:C._V._Raman#/media/File:Sir_CV_Raman.JPG

Raman joined Presidency College, Madras in 1902. He obtained a B.A degree from the University of Madras at the age of 16, securing first position in the University. He completed an M.A degree from the same university with highest distinction in 1907. While he was a college student, he contributed a few original papers in Physics which were published in the British journal *Philosophical Magazine*. Apart from his interest in science and experiments, he was also keenly interested in Sanskrit literature and read the original versions of Ramayana and the Mahabharata. Raman had interest in the physics of musical sounds. He was fascinated by the different sounds of musical instruments. He studied the acoustics of various musical instruments such as veena, violin, pianoforte, cellos, tabla and mridangam. In those times, nobody in India dared to adopt scientific research as a full time career. So, like any other bright student of the day, he decided to join Government service. He appeared in Indian Audit and Accounts Service Examination and topped the list of successful candidates. Thereafter, he was appointed Assistant Accountant General in the Imperial Government Service in

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1907 and was posted in Calcutta. There he got an opportunity to carry out his research work in Physics at the Indian Association for the Cultivation of Science founded by Dr. Amrita Lal Sircar.

Ashutosh Mukherjee, the Vice-Chancellor of Calcutta University was impressed by Raman's research work. In 1917, he offered him Palit Professorship of Physics at the Rjabazar Science College under the University of Calcutta which he readily accepted. He carried on his academic work at Calcutta University till 1933. In a short span, he distinguished himself in research work and the University of Calcutta conferred an honourary D.Sc. on him in 1921. He was elected a Fellow of the Royal Society in 1924. He soon got recognition as one of the world's renowned physicists.

C.V Raman had great fascination for colours. In 1921, during his voyage to Europe, he was greatly attracted by the deep blue colour of sea water. The unearthly beauty of the ice-blue of the Swiss glaciers made a similar impression on his mind. When he came back to India, he experimented on the diffusion of light, when passed through clear water, transparent blocks of ice and other materials. From the observations it was clear that light gets diffused through all transparent bodies, but the degree of diffusion and the state of polarization differ from one material to another.

Though Albert Einstein was the first to establish that a beam of light could also act as a fusillade of minute bullets, yet it was Raman's work that made this idea acceptable to the scientists. After Compton's discovery of the Compton Effect, Heisenberg, in 1925, predicted that a similar effect ought to be found in the case of visible light. But Raman arrived at the same conclusion before Heisenberg had made his prediction even before Compton's work. In 1928, Raman's second important discovery on the scattering of light was a new type of radiation, an eponymous phenomenon called Raman Effect. Raman illustrated that scattered light had weak components of changed wavelengths. Besides this, the exact wavelengths produced in the scattering depended on the nature of the molecules doing the scattering. The discovery of Raman Effect and Raman Spectra proved to be most useful in determining some of the fine details of molecular structure.

For conducting his experiments he used monochromatic (of one colour) radiations from mercury-arc lamp instead of sunlight. When a monochromatic beam, for example, the green light of a mercury lamp, passes through a transparent medium like benzene, one of the following two things may happen to each one of the several light bullets or photons of which the light beam consists:

(i) It may pass through the invisible inter-molecular gaps of the liquid without a close contact with any molecule of benzene, thus keeping its initial energy intact on emergence.

(ii) Otherwise, it may collide headlong with a molecule of benzene.

When a photon meets a molecule, it may emerge with some loss (or gain) of energy which it imparts to (or abstracts from) the molecule. Consequently, the energy contents of emergent photon is weakened or strengthened. The deficit (or excess) is absorbed (or surrendered) by the molecule. In the rainbow colours from violet to red, the energy content of the photons constantly reduces. Now, if the molecular encounter reduces the energy of a photon, the loss of energy shows itself in a shift of colour of the photon towards the red of the spectrum.

The Raman Effect is significant because of the reason that the associated color shift in an incidental beam of light is a measure of the energy lost by the incoming photons. Since this loss is equal to the energy gained by the molecules of the medium, it gives a measure of the increase of internal energy gained by the molecules and the atoms of the substance. Therefore, it helps in deducing the details of molecular and atomic structure of the medium. In other words, Raman provided a technique of exploring the interiors of molecules and atoms. Raman Effect proved to be valuable in understanding the physical behaviour of the liquid and crystalline states of the matter.

C.V Raman was appointed the President of Indian Science Congress in 1928. He was knighted by the British Government in 1929 and he was awarded the Nobel Prize in Physics for his discovery in 1930. He became the first Asian scientist to receive the Nobel Prize. At the presentation ceremony in Stockholm, he demonstrated the influence of the Raman Effect on different liquids including alcohol. After the ceremony, at a reception in his honour, one of the scientists remarked that they had been delighted to see the influence of the Raman Effect on alcohol earlier and that they would like to see the effect of alcohol on Raman. However, he politely refused to touch the alcoholic drinks that were served at the dinner. In 1930, he made an extensive tour of Europe and America at the invitation of several scientific organizations.

Raman was appointed as the Director of the Indian Institute of Science at Bangalore in 1933. There he founded the Indian Academy of Sciences. Till 1943, he worked, besides other things, on the theory of musical instruments particularly on the Tambura, the well-known Indian musical instrument. Recognizing the requirement of science research institutes in India, he founded the Raman Research Institute in Bangalore in 1948 and became its Director. In 1954, the Government of India honoured him with the first Bharat Ratna, India’s highest civilian award. Raman represented India at many international science organizations such as the Zurich Physical Society and the Soviet Academy of Sciences. He won the International Lenin Prize in 1957.

At the end of October 1970, Raman had a cardiac arrest and he collapsed in his laboratory. He never recovered from the illness and died on 21 November 1970 at the age of 82. The life of this great scientist was truly the life of a great seer.

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Check Your Progress

7. When did C.V. Raman win Nobel Prize for Physics?
8. In which year did C. V. Raman receive the Bharat Ratna from the Indian government?

13.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. J. C. Bose invented the 'crescograph' in which the undetectably slow growth of plant could be magnified several million times and accurately recorded.
2. He was elected a Fellow of the Royal Society in 1920 in recognition for his outstanding work.
3. P.C Ray is known as the Father of Indian Chemistry.
4. P.C Ray was knighted in 1919.
5. Srinivasa Ramanujan excelled in the field of Mathematics.
6. 'On Some Properties of Bernoulli Number' article written by Srinivasa Ramanujan was published in the Journal of Indian Mathematical Society.
7. C.V. Raman won the Nobel Prize for Physics in the year 1930.
8. C.V. Raman was felicitated with the Bharat Ratna by the Indian government in the year 1954.

13.6 SUMMARY

- The development of scientific thought in modern India can be credited to the scientists of the 19th century. Eminent scientists such as Jadish Chandra Bose, Prafulla Chandra Ray, Srinivasa Ramanujan and C.V Raman laid down a solid foundation for the progress of science despite the colonial restrictions.
- Jagdish Chandra Bose brought glory and respect for India. He is famous for his experiments in Physics on electric waves. Bose also made many other instruments famous all over the world as Bose instruments, to prove that even metals react to outward stimuli.
- Bose is famous all over the world as the inventor of Crescograph that can record even the millionth part of a millimeter of plant growth and movement. His wireless inventions too preceded those of Marconi. He was the first to invent a wireless coherer (radio signal detector) and an instrument for indicating the refraction of electric waves.

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- Prafulla Chandra Ray known as the 'Father of Indian Chemistry' was a renowned Indian scientist and teacher and one of the first modern Indian chemical researchers. He conducted the systematic analysis of numerous rare Indian minerals in 1894.
- Ray discovered the stable compound mercurous nitrite in 1896 and laid the foundation of Bengal Chemical and Pharmaceutical Works Ltd, India's first pharmaceutical company in 1901.
- P.C Ray also conducted a study of compounds of metallic elements with organic sulphur derivatives, and examined the formation and behaviours of some of their simple derivatives. He had a fascination for the history of science. In 1902, he completed his monumental work, 'History of Hindu Chemistry'.
- Srinivasa Ramaujan was one of India's greatest mathematical geniuses who have several outstanding achievements in this field to his credit. He is renowned for his contribution in the theory of numbers and properties of partition function.
- Ramanujan worked on Riemann's Zeta function, moch-theta function, modular equations, identities, theories of continued fractions and elliptic functions. Although Ramanujan was almost completely unaware of latest developments in mathematics, his mastery of continued fractions was unequaled by any living mathematician.
- C.V. Raman was an outstanding Indian physicist whose work was influential in the growth of science in India. His earliest researches in optics and acoustics – the two fields of investigation to which he has dedicated his entire career – were conducted while he was a student.
- Raman's other interests comprised the optics of colloids, electrical and magnetic anisotropy, and the physiology of human vision. He was the recipient of Nobel Prize for Physics in 1930. His finding that light is made up of particles known as photons came to be known as the Raman Effect.

13.7 KEY WORDS

- **Beam:** It refers to several parallel rays of light considered collectively.
- **Integer:** It is a number that can be written without a fractional component.
- **Modular Equation:** In mathematics, a modular equation is an algebraic equation satisfied by moduli, in the sense of moduli problem.
- **Photon:** It is a tiny particle that comprises waves of electromagnetic radiation.
- **Plant Physiology:** It is a sub-discipline of botany concerned with the functioning, or physiology, of plants.

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- **Wavelength:** In a periodic wave, the distance between consecutive points of corresponding phase.

13.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Write a short note on the early life of J. C. Bose.
2. Mention the literary works published by J. C. Bose.
3. Prepare a short note on the life of Prafulla Chandra Ray.
4. What was Srinivasa Ramanujan's role in the development of mathematics?

Long-Answer Questions

1. Jagdish Chandra Bose became famous for his experiments in Physics on electric waves.' Explain the statement.
2. Discuss the significant contribution of P. C. Ray in the field of chemistry.
3. Who was C.V Raman? Elaborate his contribution to the development of Physics.

13.9 FURTHER READINGS

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UNIT 14 PIONEERS IN MODERN SCIENCE IN INDIA-II

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Structure

14.0 INTRODUCTION

Advancements in science and technology have been the major reason for the development of human civilization. India has been contributing to the field of science and technology since ancient times. It has witnessed considerable growth in the field of science and technology since Independence. Significant achievements have been made in the areas of nuclear and space science, biology, electronics and defence. Modern India has produced a number of eminent scientists such as Homi Jahangir Bhaba, Hargobind Khorana, S.Chandrasekhar, Vikram Sarabai and A.P.J Abdul Kalam who have made major contributions to science.

The Indian Space Research Organization (ISRO), also known as the Indian space agency, was founded in 1969 to develop an independent Indian space programme. It developed rockets for launching satellites and missions to Moon (Chandrayan) and Mars (Mangalyan).

14.1 OBJECTIVES

After going through this unit, you will be able to:

- Describe the growth of nuclear energy in India under Homi Jahangir Bhaba
- Discuss the contribution of Hargobind Khorana and S. Chandrasekhar

- Discuss the career and contribution of Vikram Sarabai and A.P.J. Abdul Kalam in the development of space science in India
- Discuss India's space exploration projects Chandrayan and Mangalayan

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14.2 HOMI JAHANGIR BHABA

Homi Jahangir Bhaba was the architect of India's nuclear energy programme. He was born at Bombay on 30 October 1909. He was brought up in a rich and aristocratic family. He grew up amidst books, music and paintings. Bhaba received his school education from Cathedral and John Cannon High School. Later, he joined Elphinston College and the Institute of Science in Bombay. Bhaba's parents took a keen interest in nurturing his love for science. In 1930, he passed Mechanical Engineering Tripos in first class from Cambridge University.

Like other young men of his age and background, H.J Bhaba took off for higher studies in England., He got a fellowship at Cambridge University from 1932 to 1934. He was awarded Ph.D in 1934 by Cambridge. During these years of his European interlude, he had an opportunity to come into contact with renowned scientists such as Rutherford, Dirac, Neils Bohr and others. He worked in the extremely active Institute at Copenhagen which housed Neils Bohr's group. He also worked with the world famous scientist Fermi, who was instrumental in establishing an atomic centre at Chicago.



Fig 14.1 *Homi Jahangir Bhaba*

Source:https://commons.wikimedia.org/wiki/File:Homi_Jahangir_Bhaba_1960s.jpg

Bhaba contributed significantly to the field of atomic physics. In 1937, along with Heitler, he proposed the Cascade Theory of Electron Showers which is today known as the Bhaba-Heitler Cascade Theory. The theory explains the process of electron showers in cosmic rays. He worked out the detailed mathematical aspects of his theory. His cascade theory found practical utility when he disproved Heisenberg's idea about the nature of explosions found in high-energy cosmic-ray phenomena. He predicted that some particles in cosmic-ray showers, behaved neither like protons nor like electrons, so they must be new type of nuclear particles. He called these particles as meson. In 1938, Bhaba developed the vector theory of meson, in a Royal Society paper. In the field of Quantum mechanics, he devised a set of equations, for particles with any arbitrary spin. These are equivalent to D.F.P. (Dirac-Fierz-Pauli) equations in the three particular cases corresponding to spins 0,1/2,1.

Till 1939, he carried outstanding original research relating to cosmic radiation. He returned to India after the commencement of the Second World War. He joined the Indian Institute of Sciences at Bangalore as a Reader at the request of C.V. Raman. Soon he became a Professor of Physics. It was here that he got the idea of building a research institute for some of the new areas of physics. He took a very bold decision and wrote a letter to Sir Dorab Ji Tata suggesting that an institution should be established which would lay the foundation of India as a world nuclear power. This institute would produce its own experts and the country would not have to depend on outside sources.

As a result, Tata Institute of Fundamental Research (TIFR) was started in 1945 at Bombay and Bhaba became its Director. He believed that the only way of overcoming power hunger was through the introduction of nuclear power in a phased manner. The Atomic Energy Commission was formed in 1948 and Bhaba was appointed as its Chairman. The Commission's responsibilities comprised: a survey of Indian soils for the materials required for nuclear research, construction of atomic reactors, the purification of atomic materials, conducting fundamental research, and development of training programmes. The Commission utilized the services of scientists at TIFR. Soon the Commission's scope was expanded and the Atomic Energy Programme began to take shape.

Bhaba served as the Secretary of the Department of Atomic Energy, Government of India, from 1954 to 1966. It was due to his efforts that an Atomic Energy Establishment was founded at Trombay for the application of atomic energy for peaceful purposes. Bhaba became its first Director in 1957. At a ceremony attended by renowned international figures, on 12 January 1967, Prime Minister Indira Gandhi renamed the Trombay Establishment as Bhaba Atomic Research Centre (BARC). Bhaba worked hard to make India self-reliant in the nuclear field. He emphasized that while India needed to use the expertise already built up in other countries, its objective must be to build and utilize its own resources of scientists and technologists as well as the raw materials. With the support and

backing he received from J. R. D. Tata and Jawaharlal Nehru, Bhaba enjoyed considerable freedom to carry on his work with ease and efficiency. Reactors such as Apsara, uranium and zirconium plants, the Van de Graff and cyclotron equipment were all Bhaba's gifts to the nation.

H.J Bhaba was awarded honourary doctorates by many Indian and foreign universities including the University of Cambridge, Padua, Perth, Banaras, Agra, Patna, Lucknow, Allahabad, Andhra and Aligarh. Dr. Bhaba was awarded Adams Prize in 1942 and Hopkins Prize in 1948. In 1954, the President of India conferred him the Padma Bhushan honour for his outstanding contribution to nuclear science. In 1955, Bhaba was elected President of the first International Conference on the 'Peaceful Uses of Atomic Energy', held by the United Nations at Geneva. He remarked, 'For the full industrialization of the under-developed areas, for the continuation of our civilization and its further development, atomic energy is not merely an aid; it is an absolute necessity'. He was the first scientist to promote peaceful use of atomic energy at international forums. He was also conferred with Honorary Fellowship of the Royal Society, Edinburgh in 1957.

The crowning success of Bhaba's life-long passion came on 18 May 1974 when India carried out its first nuclear explosion for peaceful purposes at Pokhran in Rajasthan. India became the world's sixth nuclear power. However, Bhaba did not live to see his dream prosper further. The Air India Flight 101 in which Bhaba was travelling to attend an international conference crashed in a snowstorm near Mont Blanc on 24 January 1966, bringing to a tragic end the life of one of the great scientists of India. It was unfortunate that he could not survive to see the commissioning of even his first atomic power plant at Tarapur.

Check Your Progress

1. What is the main premise of the Bhaba-Heitler Cascade Theory?
2. What were the main responsibilities of the Atomic Energy Commission established in 1948?

14.3 HAR GOBIND KHORANA

Har Gobind Khorana (known as 'Gobind' to all) was born on 9 January 1922 in a small village called Raipur in Punjab (now in Pakistan). He was the youngest of five siblings in the family. Although a *patwari* (a village agricultural taxation clerk in the British India), his father was committed to educating his children with his meager earnings. Korana had his preliminary schooling at home. Later he joined D.A.V High School in Multan.

He graduated in science from Punjab University, Lahore (now in Pakistan) in 1943 and did his Masters in science in 1945. He joined the University of Liverpool in 1945 with a fellowship from the Government and received a Ph.D in

1948, working on the chemistry of melanins under Roger Beer. He did his postdoctoral studies at Switzerland with Professor Vladimir Prelog in Zurich. Here, he worked for about a year on alkaloid chemistry without any funding and had to sustain himself on his poor savings living essentially in the laboratory and surviving on rice and unpasteurized milk.

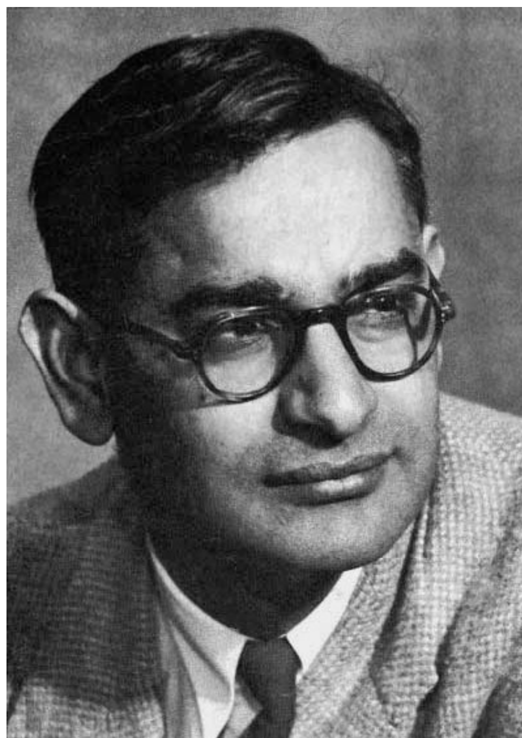


Fig 14.2 *Har Gobind Khorana*

Source: https://commons.wikimedia.org/wiki/File:Har_Gobind_Khorana.jpg

He returned to India in 1949 and found that due to the partition of India his ancestral village had ended up in Pakistan. He went to England on a fellowship to work for 2 years (1950–52) with Professor G. W. Kenner and Lord A. R. Todd in the Cambridge University on peptides and nucleotides. Since then he developed his interest in both proteins and nucleic acids. In 1952, he went to the University of British Columbia, Vancouver with a job offer and stayed there for about eight years.

Khorana joined the University of Wisconsin, Madison in 1960 and worked here for about 10 years as the Director of the Institute for Enzyme Research. In 1970, he became the Alfred Sloan Professor of Biology and Chemistry at the Massachusetts Institute of Technology (MIIT) where he worked until retirement in 2007.

In Vancouver Khorana used carbodiimides to initially synthesize the deoxy- and ribo-triphosphates and coenzyme for which he got considerable international recognition. These syntheses provided Khorana an entry into the use of chemistry to solve biological problems. Renowned contemporary biochemists such as Paul

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Berg, Arthur Kornberg, Leon Heppel, and others started visiting Khorana's laboratory in Vancouver to learn the preparation and use the new carbodiimide reagents to make nucleotides of potential biological interest.

Khorana's group at the University of Wisconsin, Madison worked hard to synthesize all the possible triplet tri-nucleotides, thus, providing a firm basis to establish the Genetic code. At the age of 46, Khorana shared the Nobel Prize for Physiology and Medicine in 1968 along with R.W Holley and M. W Nierenberg for the interpretation of the genetic code and its function in protein synthesis. It was one of the greatest scientific achievements ushering in the age of molecular biology. He was conferred with Padma Vibhushan in 1969 by the Government of India.

In 1972 Khorana's team, at the Massachusetts Institute of Technology, described the total chemical synthesis of a functional t RNA gene of yeast. It was a monumental achievement in chemical biology. In 1976, Khorana's group synthesized the first fully functional man-made gene in a living cell. The technique they initiated laid the groundwork for subsequent research on how the structure of a gene influences its function.

As a mentor, Khorana set high standards. He was loyal to the people who helped him and to the institutions where he worked. Besides the Nobel Prize, Khorana won a number of prestigious awards, including the Albert Lasker Award for Medical Research, National Medal of Science, the Ellis Island Medal of Honor, and so on.

Khorana could ignite hundreds of young minds and train them. Many of the scientists, who worked with him, are doing good job in many countries throughout the world now. In addition to his incredible scientific contributions, this is the true legacy he left behind. Though unassuming, humble and shy, Khorana was not impersonal. The warmth of his affection has been a guiding spirit for all his associates. He was more interested in the next project and experiments than cashing in on his fame. Khorana died in a hospital in Concord, Massachusetts on 9 November 2011.

Check Your Progress

3. In which university did Har Gobind Khorana begin research on nucleic acids?
4. When did Har Gobind Khorana win the Nobel Prize for Physiology and Medicine?

14.4 S. CHANDRASEKHAR

Subrahmanyan Chandrasekhar was an Indian-American astrophysicist who was born on 19 October 1910 in Lahore, Punjab, (now Pakistan) in a Tamil Brahmin family. He was known throughout his life as Chandra. His father

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Chandrasekhara Subrahmanya Ayyar was an officer in Indian Audits and Accounts Department and his mother Sitalakshmi was a woman of high intellectual attainments. C.V Raman, his paternal uncle, was Chandrasekhar's role model. When he was young his family moved from Lahore to Allahabad in 1916, and finally settled in Madras in 1918.

Chandrasekhar was educated at home until the age of 12. In middle school, his father taught him Mathematics and Physics and his mother taught him Tamil. He attended the Hindu High School, Triplicane, Madras from 1922 to 1925. He joined Presidency College, Madras (affiliated to the University of Madras) from 1925 to 1930. He obtained his Bachelor's (Honors) Degree in physics in June 1930. He was awarded a Government of India scholarship in July 1930 to pursue graduation at Cambridge, England. During his travel to England, Chandrasekhar worked out the statistical mechanics of the degenerate electron gas in white dwarf stars, providing relativistic corrections to Fowler's previous work. In his first year at Cambridge, he calculated mean opacities and applied his results to the construction of an improved model for the limiting mass of the degenerate star.



Fig 14.3 *S.Chandrasekar*

Source: https://commons.wikimedia.org/wiki/File:Subrahmanyan_Chandrasekhar.gif

Chandrasekhar completed his Ph.D degree at Cambridge in the summer of 1933 with a thesis among his four papers on rotating self-gravitating polytropes. In October 1933, he was elected to receive a Prize Fellowship at Trinity College, becoming only the second Indian to receive a Trinity Fellowship after Srinivasa Ramanujan 16 years earlier.

During this time, Chandrasekhar came into contact with British physicist Sir Arthur Eddington. In 1935, Eddington publicly ridiculed the concept of the Chandrasekhar limit at the Royal Astronomical Society in London. Although

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Eddington was later proved wrong yet this encounter caused Chandrasekhar to plan employment outside Britain. Chandrasekhar was invited by the Director of the Harvard Observatory to be a visiting lecturer in theoretical astrophysics for a three-month period. He travelled to the United States in December. In 1936, Chandrasekhar was offered a position as a Research Associate at the University of Chicago and remained there for his entire career. In September 1936, Chandrasekhar married Lalitha Doraiswamy who was his junior at the Presidency College in Madras. In 1941, he was promoted to the position of Associate Professor and to Professor in 1943 at just 33 years of age. He and his wife became citizens of the US in 1953.

Subrahmanyan Chandrasekhar is famous for his discovery of Chandrasekhar Limit. *It is* defined as the maximum mass of a stable white dwarf star. He illustrated that there is a maximum mass which can be supported against gravity by pressure of electrons and atomic nuclei. The value of this limit is about 1.44 times a solar mass. The Chandrasekhar Limit played a key role in understanding the stellar evolution. If the mass of a star exceeded this limit, the star would not become a white dwarf but it would continue to collapse under the extreme pressure of gravitational forces. The invention of the Chandrasekhar Limit resulted in the discovery of neutron stars and black holes. Depending on the mass, there are three possible final stages of a star—white dwarf, neutron star and black hole.

Other major works accomplished by Subrahmanyan Chandrasekhar comprise: stellar dynamics, including the theory of Brownian motion; the theory of radiative transfer, including the theory of stellar atmospheres and the quantum theory of the negative ion of hydrogen and the theory of planetary atmospheres, which again consisted of theory of the illumination and the polarization of the sunlit sky; hydrodynamic and hydro magnetic stability, including the theory of the Rayleigh Benard convection; the equilibrium and the stability of ellipsoidal figures of equilibrium, partly in collaboration with Norman R. Lebovitz; the general theory of relativity and relativistic astrophysics; and the mathematical theory of black holes.

Chandrasekhar got many honours for his outstanding contributions. He was bestowed the Nobel Prize for Physics in 1983 for his studies on the physical processes important to the structure and evolution of stars. He received the Royal Society's Royal Medal of 1962 and their Copley Medal of 1984. He was honoured with the Bruce medal of the Astronomical Society of the Pacific, the Henry Draper medal of the National Academy of Sciences (US) and the Gold Medal of the Royal Astronomical Society. Chandrasekhar died of a sudden heart attack at the University of Chicago Hospital on 21 August 1995.

Check Your Progress

5. Who was Chandrasekhar's paternal uncle?
6. In which year did S. Chandrasekhar receive the Nobel Prize and for which invention?

14.5 VIKRAM SARABAI

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Vikram Ambalal Sarabai was an Indian physicist who was born on 12 August 1919 at Ahmedabad in an affluent family. His initial education at a private school shaped his scientific bent of mind. After completing his studies at the Gujarat College in his hometown in 1937, he left for England to study physics at St. John's College, Cambridge. There, Sarabai earned an undergraduate tripods degree in Physical Sciences in 1939. Vikram's area of interest was cosmic rays. Cosmic rays are a stream of energy particles reaching the earth from outer space. On their way to the earth they are influenced by the sun, the atmosphere and earth's magnetism. Vikram wanted to know how the rays vary with time and the implications of this phenomenon. When the Second World War started, he returned to India and became a research scholar at the Indian Institute of Science, Bangalore, where he studied the effects of cosmic rays. It was at Bangalore, under the direct guidance of C.V. Raman that he started establishing observatories in Bangalore, Pune and the Himalayas. Vikram conducted research for a while at the central meteorological station in Poona (now Pune), and in 1943, he went to Kashmir to study the intensity of cosmic rays. After the culmination of the Second World War, he once again went to Cambridge to continue his research on cosmic rays and got his Ph.D in 1947.



Fig 14.4 *Vikram Sarabai*

Source: https://commons.wikimedia.org/wiki/File:Dr._Vikram_Sarabai.jpg

After his return from Cambridge, Vikram along with Professor K.R Ramanathan established the Physical Research Laboratory (PRL) at Ahmedabad. Known as the cradle of space sciences in India, it was devoted to the study of cosmic rays and outer space. Initially, it consisted of rooms at the Science Institute of the Ahmedabad Education Society.

Sarabai's team realized the inadequacy of evaluating the weather alone to comprehend variations in the cosmic rays; they had to associate it with the variations in solar activity. He was the pioneer researcher in the arena of solar physics. In 1955, Sarabai established a branch of the Physical Research Laboratory at Gulmarg in Kashmir. The Atomic Energy Department of the Government of India set-up a High Altitude Research Centre at the same place as the only research centre in the world at such an altitude. He also got financial assistance from the Indian Council of Scientific and Industrial Research. He was also asked to organize the Indian programme for the International Geophysical Year of 1957. Around this time, the former Soviet Union launched Sputnik-1. India decided to establish the Indian National Committee for Space Research under the Chairmanship of Vikram Sarabai. He was also responsible for the establishment of India's first rocket launching station, Space Science and Technology Centre in Thumba on the coast of the Arabian Sea on 21 November 1963 with the support of Homi Bhaba from the Atomic Energy Commission. He also launched the Experimental Satellite Communication Earth Station at Ahmedabad. He established the Rocket Launching Stations at Thumba (TELRS) and Sriharikota. He also devised plans to take education to the villages through Satellite Communication.

In 1966, Sarabai was appointed as Chairman of the Indian Atomic Energy Commission following Bhaba's unfortunate demise. Sarabai's greatest achievement was the establishment of the Indian Space Research Organization (ISRO).The pioneering work on space science and research done by Sarabai earned him Shanti Swarup Bhatnagar Medal in 1962 and Padma Bhushan in 1966. He died in his sleep at the young age of 52 on 31 December 1971. After his death, the Government of India conferred on him the honour of Padma Vibhushan in 1972. The International Astronomical Union named a crater after him on the moon in the Sea of Serenity. Vikram Sarabai is regarded as the Father of Indian Space Programme.

Check Your Progress

7. Where did Vikram Sarabai establish the Rocket Launching Stations?
8. Who is known as the Father of Indian Space Programme?

14.6 A.P.J ABDUL KALAM

Dr. Avul Pakir Jainulabdeen Abdul Kalam, the Indian scientist and politician, was born 15 October 1931 at Rameswaram in Tamil Nadu in a Muslim family. His father Jainulabdeen was a ferry owner and Imam and his mother Ashiamma was a housewife. He was a bright and hardworking student in school. After completing his education from the Scwartz Higher Secondary School, Rmamnathapuram, Kalam joined Saint Joseph College, Tiruchirappali for his graduation from where

he received his degree in Physics in 1954. He specialized in Aeronautical Engineering from the Madras Institute of Technology in 1958.

Kalam joined the Aeronautical Development Establishment of the Defence Research and Development Organization as a scientist. In 1969, he moved to the Indian Space Research Organization (ISRO) where he was appointed as the project director of India's first Satellite Launch Vehicle (SLV-III) that was both designed and produced in India.

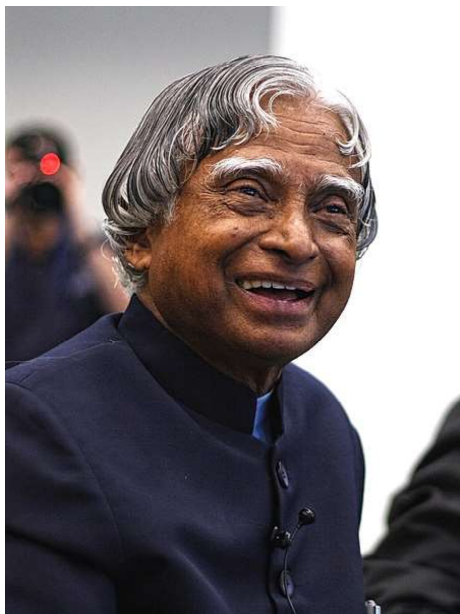


Fig 14.5 *A.P.J. Abdul Kalam*

Source: https://commons.wikimedia.org/wiki/File:A._P._J._Abdul_Kalam_in_2008.jpg

Kalam earned a degree in aeronautical engineering from the Madras Institute of Technology and in 1958 joined the Defence Research and Development Organization (DRDO). In 1969 he moved to the Indian Space Research Organization, where he was project director of the SLV-III, which put the satellite Rohini into orbit in 1980. In 1982, in his capacity as Director of DRDO, he was assigned the task of Integrated Guided Missile Development Programme (IGMDP). He developed five projects for defence services — Prithvi, Trishul, Akash, Nag and Agni. He led India into an era of self-dependence. His work in the development and operationalization of Agni and Prithvi missiles was a unique achievement. It earned for himself the title of Missile Man of India. Their successful launch made India a member of the club of highly developed countries. The light weight carbon material designed for Agni has been used to prepare calipers for the polio-affected people. The material has reduced the weight of calipers to 400 grams from 4 kgs which is a great blessing for human beings. The material has also been used in the manufacturing of spring like coils called stents (Kalam-Raju Stent), which are used in Balloon Angioplasty for treating heart patients.

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Kalam was awarded Padma Vibhushan in 1990. While serving as the Chief Scientific Adviser to the then Prime Minister, Kalam played a significant role in heading the Pokhran-II nuclear testing leading to him being known as the best nuclear scientist of India at that time. The nuclear testing under Kalam's supervision during the period of July 1992 to December 1999 made India a nuclear-armed state.

Kalam was the scientific advisor to the Defense Minister from 1992 to 1997, and he later served as the principal scientific advisor (1999–2001) to the Government with the rank of cabinet minister. His prominent role in India's 1998 nuclear weapons tests strengthened India as a nuclear power and established Kalam as a national hero, although the tests caused great concern in the international community. In 1998, Kalam put forth a nationwide plan called Technology Vision 2020, which he described as a road map for transforming India from a less-developed to a developed society in 20 years. This vision comprised increasing agricultural productivity, emphasizing technology as a vehicle for economic growth, and widening access to healthcare and education.

Kalam was awarded with the Bharat Ratna in 1997 for his contribution to the scientific research and modernization of defence technology in India. Kalam easily won the election and was sworn in as India's 11th President in July 2002. He left office at the end of his term in 2007. Upon returning to civilian life, Kalam remained committed to using science and technology to transform India into a developed country. In 2012, Kalam along with cardiologist Soma Raju, designed a rugged tablet computer for better healthcare administration in the rural pockets of the country. They termed it the 'Kalam-Raju tablet.' Kalam authored several books, including an autobiography, *Wings of Fire* (1999).

Kalam collapsed and died of cardiac arrest while delivering a lecture at the Indian Institute of Management, Shillong on 27 July 2015. Even today his contributions are still remembered as some of the best scientific and technological developments in India.

Check Your Progress

9. Name the famous scientist of India who earned the sobriquet 'Missile Man'.
10. When did A.P.J Abdul Kalam receive Bharat Ratna for his contribution to the scientific research and modernization of defence technology in India?

14.7 CHANDRAYAN PROJECT

Chandrayan is a Hindi word which means 'Journey to the Moon' (Chandra - Moon, yaan - ship). It was the first Indian Mission to the Moon devoted to high-resolution remote sensing of the lunar surface characteristics in visible, near infrared, X-ray and low energy gamma ray regions. It was the first collaborative mission

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between the European Space Agency (ESA) and the Indian Space Research Organization (ISRO), and also the first Indian scientific mission leaving the vicinity of Earth. Some of the major tasks of this project included realization of the objective of harnessing the science payloads, lunar craft and the launch vehicle with appropriate ground support system including DSN station, integration and testing, launching and achieving lunar orbit of ~100 km, in-orbit operation of experiments, communication, telemetry data reception, quick look at data and archival for scientific application by renowned group of scientists.

The mission consisted of eleven separate instruments. Eight of them have been developed and manufactured by ISRO and three of them have been delivered by ESA. These are the following:

(i) TMC (Terrain Mapping Camera)
(ii) HYSI (Hyper Spectral Imager)
(iii) LLRI (Lunar Laser Ranging Instrument)
(iv) HEX (High Energy X-ray/gama-ray Detector)
(v) MIP (Moon Impact Probe)
(vi) CIXS-2 (Chandrayan Imaging X-Ray Spectrometer)
(vii) SARA (Sub-keV Atom Reflecting Analyzer)
(viii) SIR 2 (Near Infrared Spectrometer)
(ix) Mini-SAR (Miniature Synthetic Aperture Radar)
(x) M3 (Moon Mineralogy Mapper)
(xi) RADOM (Radiation Dose Monitor Experiment)

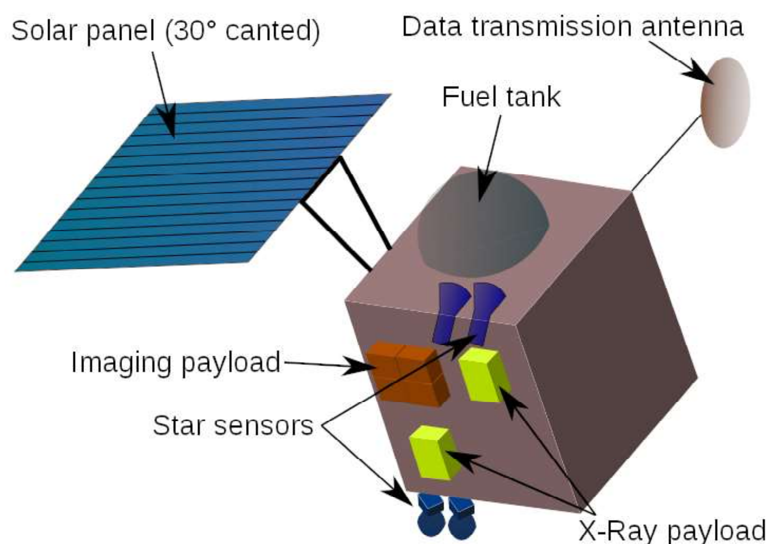


Fig 14.6 *The Chandrayan Project*

Source:https://commons.wikimedia.org/wiki/File:Chandrayan-1.svg

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On 22 October 2008 Chandrayan-1 was launched on board a Polar Satellite Launch Vehicle (PSLV) from the Satish Dhawan Space Center in Sriharikota, India. The spacecraft was first injected into an elliptical 7-hr orbit around Earth, between 255 km and 22860 km above the Earth. After five engine firings, Chandrayan-1 spiraled outwards in progressively elongated ellipses around Earth, until it reached its lunar transfer orbit with the lunar orbit insertion point and enter a nearly circular orbit at a height of about 1000 km over the Moon. After two-weeks of in-orbit exercises, the satellite reached its final circular, polar orbit at an altitude of 100 km. The mission was planned to operate for at least two years.

On 14 November 2008 the Moon Impact Probe was dropped to the Moon to place close to the South Pole, where ice may exist in areas where there was no sunlight. It carried three instruments: a video imaging system, a radar altimeter and a mass spectrometer. The imaging system took pictures of the Moon as it advanced the surface, the radar was used to ascertain the altitude, and the mass spectrometer was used to study the thin lunar atmosphere. As it descended, the probe transmitted pictures to the orbiter that were later downloaded to Earth.

Chandrayan-1 revealed the competence of Indian scientists to resourcefully explore space. It demonstrated many things comprising India’s capability to do meaningful science at low cost, its ability to undertake leadership in a cooperative space venture and develop the essential technology within a given time frame. This mission made the outside world to look at India with greater respect and stimulated student community within India. It became a landmark not only in the history of Indian space programme, but in the history of India itself.

One of the main aims of Chandrayan-1 was to further expand the knowledge about the moon, make more progress in space technologies, particularly by decreasing the various internal ‘organs’ of a satellite or a spacecraft and provide challenging opportunities to India’s young scientists to conduct research about moon. Chandrayan-1 collected enormous scientific data and pictures. It detected water molecules on the moon which was a major breakthrough. Before this mission, scientists were unsure about the presence of water on the moon. Apart from this, scientists were able to ascertain the height and depth of various features on the surface of moon. Thus, Chandrayan-1 proved to be a symbol of India’s success in space.

Another mission to moon called Chandrayan-2, was launched by India on 22 July 2019 from Satish Dhawan Space Centre, Sriharikota. It was an integrated 3-in-1 spacecraft of around 3,877 kg comprising an Orbiter of the Moon, Vikram (named after Vikram Sarabai)-the lander and Pragyan (wisdom)-the rover, all equipped with scientific instruments.

The Chandrayan-2 was India’s first attempt to land on the surface of moon. ISRO had planned the landing on the South Pole of the lunar surface. However, the lander Vikram had-landed in September 2019. Its orbiter, which is still in the lunar orbit, has a mission life of seven years.

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The objective of this mission was to consolidate the evidence of water molecules shown by Chandrayan-1 and study the extent and distribution of water on the Moon. It aimed to study topography, seismography, composition and atmosphere of the lunar surface.

It also aimed to study ancient rocks, fossils and craters which may offer clues of origin and evolution of the Moon. Thus, it can enhance our understanding of the early solar system as well.

Check Your Progress

11. When did ISRO launched India's first lunar probe Chandrayan-1?
12. Name the place from where Chandrayan-1 was launched.
13. When was Chandrayan-2 mission launched?

14.8 MANGALYAN PROJECT

The success of the Chandrayan mission initiated the quest for Mars through the Mars Orbiter Mission (MOM) or the Mangalyan (Hindi: "Mars Craft"). The Indian Space Research Organization (ISRO) launched this unmanned Mars Orbiter Mission on 5 November 2013, using its Polar Satellite Launch Vehicle (PSLV) from the Satish Dhawan Space Centre on Sriharikota Island, Andhra Pradesh. India became the only country to orbit Mars in its first attempt. The success of Mangalyan put India in the elite club of countries to have achieved interplanetary missions. The total cost of this mission was approximately ₹ 450 Crore.



Fig 14.7 *The Mangalyan Project*

Source:https://commons.wikimedia.org/wiki/File:PSLV_Mangalyan.jpg

The Mangalyan project was designed to study planet Mars from orbit. Its main objectives were to demonstrate India's rocket launch system, spacecraft construction and operational capabilities. In particular, the main objective of the project was to develop the technology necessary for the operation, satellite design, planning, and management of interplanetary missions. The scientific objectives included exploration of Mars' surface features, morphology, mineralogy and atmosphere.

The Government of India approved the MOM project in August 2012, a mere 15 months before its launch. ISRO was able to keep mission costs down by basing MOM's design on that of Chandrayan-1. Because the PSLV did not have the power to place the 1,350-kg (3,000-pound) probe on a direct trajectory, the spacecraft used low-power thrusters to raise its orbit over a period of four weeks until it was released of Earth's gravity on December 1 and headed to Mars.

On 24 September 2014, it reached Mars and the spacecraft entered a highly elliptical orbit of 423 × 80,000 km (262 × 50,000 miles), which enabled it to take pictures of one entire Martian hemisphere at a time. The spacecraft's instruments includes a color camera, a thermal infrared sensor, an ultraviolet spectrometer to study deuterium and hydrogen in Mars's upper atmosphere, a mass spectrometer to study neutral particles in the Martian exosphere, and a methane sensor. MOM arrived at Mars in time to observe Comet Siding Spring when it flew by the planet at a distance of 132,000 km (82,000 miles) on 19 October 2014.

When Mangalyan entered the orbit of Mars, it provided an overwhelming amount of data back to Earth. The Mars Color Camera (MCC) on-board the orbiter had snapped nearly one thousand images and prepared the Mars Atlas, as of 2018. Mangalyan is the first artificial probe to click the full disk of Mars in one view frame and also, peek into the dark side of Deimos, a Martian moon.

At present, the ISRO satellite is in good condition and continues to perform its tasks, as expected. However, the orbiter has faced a number of challenges, during the course, even before it could launch. From a tight launch window to solar conjunction, it has had it all and yet, held itself together till date.

Check Your Progress

14. When did ISRO launch Mars Orbiter Mission or the Mangalyan Project?
15. What was the total cost of the Mangalyan mission?

14.9 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. In 1937, Bhaba along with Heitler, proposed the Cascade Theory of Electron Showers which is today known as the Bhaba-Heitler Cascade Theory. The

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theory explains the process of electron showers in cosmic rays. His cascade theory found practical utility when he disproved Heisenberg's idea about the nature of explosions found in high-energy cosmic-ray phenomena. He predicted that some particles in cosmic-ray showers, behaved neither like protons nor like electrons, so they must be new type of nuclear particles. He called these particles as meson.

2. The Atomic Energy Commission was formed in 1948 and Bhaba was appointed as its Chairman. The Commission's responsibilities comprised: a survey of Indian soils for the materials required for nuclear research, construction of atomic reactors, the purification of atomic materials, conducting fundamental research, and development of training programmes.
3. Har Gobind Khorana began research on nucleic acids at the Cambridge University.
4. Har Gobind Khorana won the Nobel Prize for Physiology and Medicine in the year 1968 for deciphering the genetic code.
5. C. V. Raman was Chandrasekhar's paternal uncle.
6. S. Chandrasekhar received the Nobel Prize for Physics in 1983 for his studies on the physical processes important to the structure and evolution of stars.
7. Vikram Sarabai establish the Rocket Launching Stations at Thumba and Sriharikota.
8. Vikram Sarabai is known as the Father of Indian Space Programme.
9. A.P.J Abdul Kalam earned the sobriquet 'Missile Man'.
10. A.P.J Abdul Kalam received Bharat Ratna for his contribution to the scientific research and modernization of defence technology in India in the year 1997.
11. ISRO launched India's first lunar probe Chandrayan-1 on 22 October 2008.
12. Chandrayan-1 was launched from the Satish Dhawan Space Center in Sriharikota, India
13. Chandrayan-2 mission was launched on 22 July 2019.
14. ISRO launched the Mars Orbiter Mission or the Mangalyan Project on 5 November 2013.
15. The total cost of the Mangalyan mission was ₹ 450 Crore.

14.10 SUMMARY

- India has been contributing to the fields of science and technology since ancient times. It has witnessed considerable growth in the field of science and technology since Independence.

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- Modern India has produced a number of eminent scientists such as Homi Jahangir Bhaba, Hargobind Khorana, S.Chandrasekhar, Vikram Sarabai and A.P.J Abdul Kalam who have made major contributions to science.
- Homi Jahangir Bhaba was the architect of India's nuclear energy programme. In 1937, along with Heitler, he proposed the Cascade Theory of Electron Showers which explains the process of electron showers in cosmic rays.
- Bhaba served as the Director of TIFR as well as Chairman of Atomic Energy Commission. It was due to his efforts that an Atomic Energy Establishment was founded at Trombay. It was renamed as Bhaba Atomic Research Centre.
- Har Gobind Khorana was a biochemist who received the 1968 Nobel Prize in Physiology and Medicine for his work in deciphering the genetic code and who was also the first scientist to create an artificial gene.
- Subrahmanyan Chandrasekhar was an Indian-American astrophysicist. He is famous for his discovery of Chandrasekhar Limit. He was bestowed the Nobel Prize for Physics in 1983 for his studies on the physical processes important to the structure and evolution of stars.
- Vikram Ambalal Sarabai was an Indian physicist who started a project for the fabrication and launch of an Indian satellite. He was the founder of Indian Space Research Organisation and was regarded as the 'Father of Indian Space Programme'.
- A.P.J Abdul Kalam was an Indian scientist who was assigned the task of project IGMDP. It produced the first Prithvi missile in 1988 and then the Agni missile in 1989.
- Due to Kalam's contribution to the development of missiles he was known as the Missile Man of India. He was awarded Bharat Ratna in 1997.
- The Chandrayaan project also known as the Indian Lunar Exploration Programme is an ongoing series of outer space missions by the Indian Space Research Organization (ISRO). The programme includes lunar orbiter, impactor, soft lander and rover spacecraft.
- Chandrayan-1 was launched on 22 October 2008 on board a Polar Satellite Launch Vehicle (PSLV) from the Satish Dhawan Space Center in Sriharikota, India. It proved to be a symbol of India's success in space.
- Another mission to moon called Chandrayan-2, was launched by India on 22 July 2019 which was India's first attempt to land on the surface of the moon.
- The success of the Chandrayan mission initiated the quest for Mars through the Mars Orbiter Mission (MOM) or the Mangalyan. It was launched by ISRO on 5 November 2013. It was designed to study planet Mars from orbit.

- The Indian Space Research Organization (ISRO), the Indian space agency launched missions to moon (Chandrayan) and mars (Mangalyan).

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14.11 KEY WORDS

- **Astrophysics:** It is a branch of astronomy dealing with the physical nature of stars and other celestial bodies, and the application of the laws and theories of physics to the interpretation of astronomical observations.
- **Caliper:** It is a metal support for a person's leg.
- **Cosmic Rays:** These are high-energy protons and atomic nuclei that move through space at almost the speed of light.
- **Genetic Code:** It is the sequence of nucleotides in deoxyribonucleic acid (*DNA*) and ribonucleic acid (RNA) that determines the amino acid sequence of proteins.
- **Payload:** It is the carrying capacity of an aircraft or launch vehicle, usually measured in terms of weight. It may comprise cargo, passengers, flight crew, munitions, or other equipment.
- **White Dwarf Star:** A white dwarf, also called a degenerate dwarf, is a stellar core remnant composed mostly of electron-degenerate matter.

14.12 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Assess the contribution of Homi Jahangir Bhaba in the growth of nuclear energy in India.
2. What is the contribution of S.Chandrasekhar to physics?
3. What is India's Moon mission Chandrayan? Explain.

Long-Answer Questions

1. Discuss the significance and contemporary relevance of Nobel Laureate Har Gobind Khorana's contributions to biology.
2. Discuss the significant contributions of Vikram Sarabai in building India's Space Program.
3. Assess the contribution of aerospace scientist A.P.J Abdul Kalam to the development of space technology in India.
4. Discuss Mars Orbiter Mission or Mangalyan.

14.13 FURTHER READINGS

NOTES

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